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The Scottish Species of *Allagecrinus*.

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(PLATES XXIII–V.)

INTRODUCTION.

SINCE the publication of Carpenter and Etheridge's paper in 1881,[1] in which the characters of *Allagecrinus* were first made known to us, few records have been noted of any other Scottish specimens belonging to the genus. The specimens figured and described by the above authors were obtained from shale collected by the late Mr. Bennie of the Scottish Geological Survey, the localities being Carlops; Catcraig, near Dunbar; Burlage, near Dunbar; Whitebaulks, near Linlithgow; Addiewell and Roscobie, all in what may be called the East of Scotland; together with a few from Howood and Carluke in the West of Scotland.

Since 1881, the only other records I can find of similar specimens are those noted by Mr. John Smith in the *B.A. Handbook on the Clyde Drainage Area* for 1901, p. 509, where it is stated that *Allagecrinus austinii* occurs at Howood and Dalry and is noted as common at the former locality. Besides Roscobie, I had long known that these microscopic crinoids occurred plentifully at No. 1 Bed, Invertiel, and recorded the fact in *Trans. Geol. Soc. Glas.*, xvi, iii, 1917–18, 387. My specimens agreed generally with those figured by Carp. and Eth.

Allagecrinus austinii is such a peculiar type of crinoid that due prominence has been given to it in the literature of the Crinoidea in general. The figures given by our authors on plates xv and xvi of their paper show a great variety of size, shape, and ornamentation. They are, however, all grouped under one species, viz. *Allagecrinus austinii*, and in the opinion of the authors exhibit a series from the

[1] *Annals and Mag. Nat. Hist.*, **5**, 281–97.

youngest up to the adult form. This opinion was arrived at only after great consideration. About three years ago my attention was specially drawn to the subject in communications from Dr. Bather and particularly from Professor Wanner, of Bonn. The latter stated definitely that he considered Carp. and Eth. were wrong in their ideas about the small specimens figured and that these specimens belonged to more than one species. I must here express my warmest thanks to Professor Wanner who, with the greatest kindness, sent me for study in 1928 a MS. copy of his then unpublished works on the Timor *Allagecrini*,[1] in which are described nine new species of *Allagecrinus*, and one redescribed from a former paper.[2] I was thus in a position to understand his arguments, which were based on his experience with the Timor species.

In 1929, I also received Professor Yakovlev's paper on a Permo-Carboniferous Echinoderm fauna from the Urals,[3] in which two new species of *Allagecrinus* are figured and described. Thus the range of the genus has been considerably extended in recent years.

Rowley had, of course, in 1895 recorded the occurrence in the U.S.A. of minute calices very similar to our smaller Scottish forms to which he gave the name *Allagecrinus americanus*.[4] Last year there was published an illuminating paper by Mr. J. Marvin Weller on another assemblage of American forms most of which are assigned to the family Allagecrinidae. In this communication, Mr. Weller also expresses doubts as to the correctness of Carp. and Eth.'s conclusions and he transfers Rowley's *A. americanus* into a new genus *Hybochilocrinus*.[5]

Wachsmuth and Springer in 1882 [6] described a small crinoid from rocks of Chester age which they named *A. carpenteri*, but in 1923 the species was removed to *Catillocrinus* by Frank Springer.[7]

My object in taking up the subject was to try and find evidence in support or otherwise of Carp. and Eth.'s opinions and from the evidence now collected I think these authors' ideas as to the majority of the smaller specimens they figured being the young of the large ones must be rejected. I therefore agree with Professor Wanner and Mr. Weller that these small specimens belong to different species which it is the purpose of the present paper to describe. At the same time Carp. and Eth. were so far right in that their *Allagecrinus austinii* does pass through a series of young stages dissimilar to one another in number of arm-bearing radial facets, etc. Other points, such as

[1] "Neue Beiträge zur Kenntnis der Permischen Echinodermen von Timor. I, *Allagecrinus*," 1929; and III, "*Hypocrininae, Paracatillocrinus* und *Allagecrinus dux*," 1930.

[2] "Die Permischen von Timor," 1924.

[3] "Extrait de tome xlvi des *Bulletins du Comité Geologique*," 181–91, 1927.

[4] *The American Geologist*, xvi, No. 4, 219–20.

[5] *Illinois State Geol. Survey, Report of Investigations*, No. 21, Urbana, Illinois, 1930.

[6] *Ill. State Mus. Nat. Hist. Bull.*, 40–3.

[7] *Smithsonian Miscellaneous Coll.*, lxxvi, No. 3.

the discovery of the oral arch in the complete "adult" type specimen of *A. austinii* and important features connected with it, have emerged from the study and are given further on.

For the purpose of this research I have collected quantities of shale from Invertiel, Roscobie, Muirkirk, etc., and from Carlops the type locality of the so-called "adult" *A. austinii* of Carp. and Eth. As regards Muirkirk, I have had the privilege of studying ten "adult" specimens lent me by Mr. J. B. Simpson, of the Scottish Geological Survey. These specimens belonged to the collection of Carboniferous fossils made by the late Mr. Adam Whyte, of Muirkirk, and which has been acquired by Mr. Simpson and handed over by him to the University of Aberdeen. I have to thank Mr. Simpson very heartily for the loan of these specimens. They have thrown a flood of light on the structure of the Scottish *Allagecrinus*. I have also had the privilege of studying the "adult" type specimens of Carp. and Eth. (figs. 1, 2, and 6, pl. xv of their paper and Figs. 14, 14*a*, 15, 16, 17, and 18, Pl. XXIV, and Text-figs. 1–4 of present paper), which are preserved in the collection of the Scottish Geological Survey in Edinburgh. This I owe to the kindness of Dr. John Pringle and I have to thank him for the loan of the specimens and permission to photograph them, etc. He has also been good enough to allow me to examine at my leisure a series of small specimens belonging to the collection of the late Mr. John Smith, now incorporated in the collection of the Scottish Geological Survey at Southpark, Edinburgh.

Material.

The specimens examined in the course of this work number over 1,063 individuals. Of these, 869 are from No. 1 Bed, Invertiel, 4 from Roscobie, and 110 from Carlops—all in my own collection. These three localities are in the Lower Limestone Group of the Scottish Lower Carboniferous classification. All the specimens from Invertiel were found in No. 1 Bed.[1] Quantities of weathered shale were washed and from the residue the small calices of *Allagecrinus* were obtained. In individuals this material was very rich. To give some idea of the rate of progress the average takings were ten per hour. This includes all sizes of specimens. Only two of the so-called "adult" examples of *A. austinii* were obtained, however, the others being the small or "young" individuals of Carp. and Eth. At Carlops, the quarry from which Mr. Bennie collected his specimens of "adult" *A. austinii*, has not been worked for over forty years and consequently all the spoil heaps and the greater part of the section are now grassed over. For my purpose I was compelled to take the weathered shale from below the grass and this material gave some trouble in washing. The residue, however, was remarkably rich in microzoa

[1] *Trans. Geol. Soc. Glas.*, xvi, iii, 1917–18, 366.

and yielded the above-mentioned 110 specimens. Six of these are well-preserved examples of the "adult" *A. austinii*. Associated with *Allagecrinus* were great numbers of the blastoid *Astrocrinites benniei* Eth., jun., several quite uncrushed, which is the usual condition of these fossils in washed shale. I also obtained a fair specimen of the rarer blastoid *Phenoschisma benniei* Eth. and Carp., together with some ambulacral areas of the same species. Crinoid fragments occurred in large numbers, principally stems, but I obtained a few small crushed crowns, also well-preserved cups of *Zeacrinus koninckı* Bather; *Eupachycrinus calyx* MacCoy; *Ulocrinus globularis* de Kon; *Mespilocrinus* near *forbesianus* de Kon.; spindle-shaped stems of probably a species of *Mespilocrinus*; scattered plates of cup and tegmen of two spp. of *Platycrinus*, and an excellently preserved small complete crown of a crinoid unknown to me. Various other species of microzoa were abundant. As compared with the Invertiel material, however, the rate of getting specimens of *Allagecrinus* was much slower, the average takings being only two per hour.

I have not yet completed the examination of the washed shale from Roscobie so that the total from this locality only numbers four, and all are small specimens.

Fifteen specimens are from the Upper Limestones of the Garpel Water section, Muirkirk, of which ten were collected by the late Adam Whyte, three by the late John Smith, and the other two by myself.

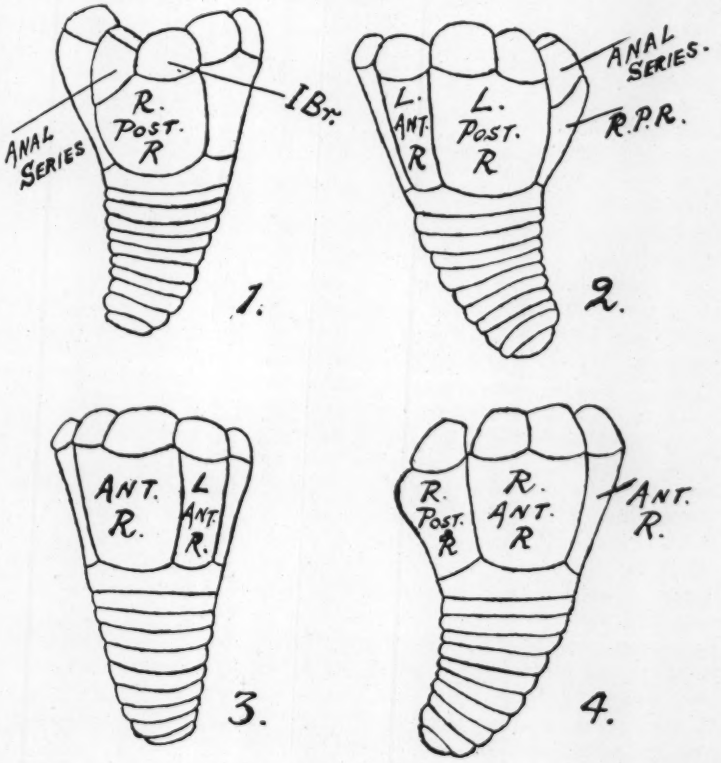
Sixty-eight are in the collection of the late John Smith, now in the possession of the Scottish Geological Survey in Edinburgh. Most of Mr. Smith's specimens come from localities in the Lower Carboniferous Limestones of the West of Scotland, such as Howood, etc., probably on or near an equivalent horizon to those from Invertiel and Carlops. The exceptions include the three noted above, which are from the Garpel Water section of the Upper Limestones at Muirkirk, and probably from the same bed as those collected by Mr. Whyte and myself. Mr. Smith's specimens are labelled "Tibby's House". Mr. Whyte's cards, on which the specimens are mounted, only have "Upper Limestones" on them. The shale from which I obtained my two specimens crops out below a waterfall, about midway between "Tibbie Pagan's Limestone" and the Blue Tour Limestone. There is evidence on the ground to show that the weathered outcrop of this shale has been more or less grassed over in recent years, and Mr. Smith's and Mr. Whyte's specimens were collected many years ago, when conditions were no doubt more favourable for securing disintegrated shale. The Blue Tour Limestone of this area is generally considered to be the equivalent of the Jenny Pate Limestone of Fife.[1] The Muirkirk specimens,

[1] *Geol. Surv. Memoirs:* "Economic Geology of the Ayrshire Coalfields," Area III, 1930, 31.

therefore, come from a horizon very far removed and considerably later in time than those from the other West of Scotland localities of Mr. Smith's collection, or those from Carlops, Roscobie, and Invertiel.

The Scottish Species.

On going over such a large number of specimens, the majority of which are so tiny in size, one is naturally first attracted by the larger individuals. The study of these together with a comparative



Figs. 1 to 4.—*Allagecrinus austinii*, the nearly complete "adult" type specimen of Carp. and Eth. from Carlops. Collection of Scottish Geological Survey. × 11.

examination of the smaller specimens has forced me to the conclusion that we are here dealing with five distinct species, which I propose to name as follows: *Allagecrinus austinii* Carp. and Eth., *A. garpelensis* sp. nov., *A. biplex* sp. nov., *A. scoticus* sp. nov., and *A. elongatus* sp. nov.

(1) *Allagecrinus austinii* Carp. and Eth.
Annals and Mag. Nat. Hist., **5**, vii, April, 1881, pl. xv, figs. 1, 2, and 6.

The larger individuals, which agree in all respects with the so-called " adult " forms of Carp. and Eth., consist of the two from Invertiel and six from Carlops in my collection, and one from Howood in the John Smith collection. In addition there are the three " adult " type specimens of Carp. and Eth. already alluded to. An examination of these, together with the group of specimens from Muirkirk to be noticed later, which are all of " adult " size, shows that Carp. and Eth. were mistaken in some of their conclusions. First of all with regard to the type specimens themselves. These, the three " adult " forms of Carp. and Eth., I take as syntypes. The specimens are preserved in the Scottish Geological Survey Collection in the Royal Scottish Museum in Edinburgh, tablets numbered 1602 and 1608. On 1602 is mounted the original of Carp. and Eth.'s figs. 2*a*, *b*, and *c* of plate xv of their paper. This is the most complete example, having the stem in place and parts of the arms lying over the top of calyx (Pl. XXIV, Figs. 16, 17, and 18, and Text-figs. 1–4 of present paper). The specimen originally had three arms, but when I received it two arms only were in position, the third—one of the outer ones—being missing. Both it and the middle arm had obviously been removed by Carp. and Eth. to look for the orals. Afterwards the middle arm had been gummed on, the outer having evidently been lost. The whole specimen was covered with a film of gum, and on soaking in water the middle arm came away. Cleaning down between the brachials I exposed the interior of the calyx, in which may be seen the remains of the oral arch. The two anterior orals are very prominent, but towards the posterior the other orals are considerably sunken in the calyx and more difficult to see (Fig. 18, Pl. XXIV). Carp. and Eth. have missed these plates altogether since they remark on the absence of an oral arch in all three " adult " type specimens and referring to this particular specimen say : " Had such a structure existed it would assuredly have been preserved." Their failure to discover the oral arch has led to a complete misconception in our ideas of the structure of the calyx in the type form. It is perfectly clear from the evidence of this specimen alone that the " adult " *A. austinii* possessed an oral arch, and the additional specimens since collected only confirm this statement. Another new fact brought out by the study of the " adult " type specimens and the others from Carlops and Muirkirk is that on the ventral surface there was an anal opening leading into the calyx. This opening is situated at the proximal end of posterior oral. A characteristic and correlated feature also is that the right posterior radial is always differentiated since the left shoulder of this plate slopes down below the level of the adjoining radial. The whole of this shoulder is occupied by a plate, which does not reach quite to the level of the first primibrachs. It tapers somewhat,

and in most of the specimens where it is preserved it is surmounted by another plate much lower in height which, in the living crinoid, was succeeded by others, giving an arm-like appearance to the whole series. Although arm-like, this series of plates are anal plates in the sense that they guard the anal opening and probably functioned in directing the faecal stream or in closing over the anal orifice; or, as in *Catillocrinus*, they may have continued upwards as a sort of tube. I see no indication of this, however. They had some power of movement since the facet on left shoulder of R P R, on which the lowest plate lies, is pierced by a canal and articular ridge much as in the other radial facets. The canal and ridge, however, are rather closer to the outside lip of the radial than is the case with the other radial facets; and as far as I can see the lowest anal plate was thinner than the IBr_1, being more evenly hollowed out on the inner side, not finely grooved in the manner of the IBr. Such features are noticeable in all the specimens. The oral arch and ventral aspect in general are best seen in the Muirkirk specimens, and I give top views of two of these on Figs. 9 and 10, Pl. XXV. These specimens are excellently preserved, and although I place them under another species, *A. garpelensis*, to be immediately referred to, they agree in all their essential ventral characters with *A. austinii*. In Fig. 9 the IBr_1 are in position excepting on Ant. R. The two plates of the anal series are seen at bottom of photograph resting on left shoulder of R P R, and the anal opening is noticeable on the inner side of topmost plate of the anal series. In Fig. 10 all the primibrachs are absent, also the anal series, and the anal opening into calyx is distinctly seen at bottom of photograph (compare also Text-fig. 11). The plates of the anal series are well shown in the type specimen No. 1602, although Carp. and Eth. failed to notice them owing to not having cleaned out the matrix on the top of specimen.

Tablet No. 1608 of the Survey Collection contains the two large cups, originals of Carp. and Eth.'s figs. 1*a* and *b*, and 6*a* and *b* of their pl. xv. In these, however, the oral arch is missing, but they show well the characters of the radial facets, the irregular number of arms borne by the radials, and the inequality in width of the radials themselves, the last a character specially commented on by Carp. and Eth. and later authors. The orientation of the tops of the cups on Carp. and Eth.'s figs. 1*b* and 6*a* of their pl. xv is wrong, the sloping shoulder of the R P R being in each case at the top right-hand corner of the figs. The correct position is that given on our Fig. 14*a*, Pl. XXIV, where the R P R is at the bottom of photograph, and in a stereoscopic view it may be noticed that the facet on left shoulder of this Plate differs from the other R facets and is hollowed out on the inner side for the passage of the rectum. This is a photograph of Carp. and Eth.'s specimen 1*b*. The structure and length of the IBr_2 and IBr_3 are shown on Carp. and Eth.'s fig. 2*c*, pl. xv. No other specimen here dealt with shows more than the IBr_1 in position.

Of the additional forms collected from Invertiel and Carlops,

I am giving photographs on Pl. XXIV, Figs. 9, 10, 11, 12, and 19, and Mr. Smith's specimen from Howood on Fig. 8 of the same Plate. These give a fair idea of the general aspect of the calyx. Figs. 8 and 9 have the oral arch in position. Before noticing the irregular number of arms, etc., several smaller specimens must now be dealt with.

On going over all the collected material I have made a special search for transitional or intermediate forms, i.e. my aim has been to find among the smaller individuals specimens which might show characters that would indubitably stamp them as the true young of *A. austinii*. It is only natural to suppose that at localities like Invertiel and Carlops, where the " adults " in the sense of Carp. and Eth. are found, some young individuals must occur. On Plates XXIII and XXIV I am showing photographs of several examples which I have come to the conclusion are the true young of *A. austinii*. There are altogether five specimens from Invertiel and four from Carlops. Although they are a somewhat aberrant group, they are all distinguished by features which seem to me to link them up with the larger specimens while at the same time they are different from all the other small specimens. For example, these specimens are characterized by having the R P R differentiated. It is clearly seen in most of the specimens ; in one or two it is more difficult to detect. In two or three examples a somewhat rounded plate lies on the left shoulder of the R P R, and is clearly the anal plate and beginning of the anal series. The inequality in width of the radials is also noticeable, but the most striking feature is the irregular way in which the radial facets are developed. In some specimens certain radial facets are not developed at all, the top of the radials being joined close in line with the orals, giving us specimens which before entombment had only two, three, or four arms, as the case may be. Such features, I have little doubt, are correlated with the irregular number of arm-bearing radials in the adult. Thus, Fig. 2, Pl. XXIV, or Figs. 39 and 40, Pl. XXIII, the same specimen more highly magnified, has only two arm-bearing radial facets developed. The height of the calyx over all is 1·3 mm. by ·9 mm. at widest from edge to edge of arm-bearing R R, and ·7 mm. at narrowest, as shown in Fig. 39 on Pl. XXIII. I am not quite sure about the position of these arm-bearing radials, as the anal plate is difficult to see in this specimen, but they are probably the R P R and Ant. R. Then in Fig. 3 Pl. XXIV, and Figs. 41, 42, and 43 of Pl. XXIII, which is the same specimen more highly magnified, all the R R have well-developed arm-bearing facets, excepting the Ant. R, which is joined up closely with the oral above. This is well seen in Fig. 41, Pl. XXIII. In this specimen also the rounded anal plate is specially well shown, and may be noted from Figs. 42 and 43 on the same Plate. The height of the calyx here over all, i.e. including the oral arch, is 1·6 mm. by 1·3 mm. at widest, as in Fig. 42, and 1·2 mm. at narrowest, as in Fig. 41. In Fig. 43 a suture line between basals may be noticed at bottom of R P R. This is the only instance

of this kind I have observed among the specimens. The proximal columnal is adherent to this specimen as well as in some of the others. In Fig. 4, Pl. XXIV, we have a specimen 1·5 mm. high by 1·2 mm. by 1 mm., which has only three arm-bearing radials, but their position is uncertain.

In Fig. 5, Pl. XXIV, we have another example with four arm-bearing R R only, the armless R being the anterior as in Fig. 3. It is a slightly larger specimen. Fig. 6 again, on the same Plate, has only four arm-bearing R R, the armless R being the anterior. In Fig. 7 we reach a form which has all five radial facets well developed. In this specimen the R P R is very noticeable as a wider plate with the left shoulder well below the level of L P R. Another specimen about the same size from Invertiel has all the five R R well developed. One of the remaining specimens from Carlops is very slightly larger than Fig. 2, Pl. XXIV. It also has only two radial facets developed. The other from Carlops measures about 1·7 mm. high and has only three radial facets developed, the other two R R being in line with the orals. In the better-preserved of these specimens, such as Fig. 3, Pl. XXIV, the L A R is the narrowest plate, and in this feature they resemble the "adult" *A. austinii*. None of the developed R R are axillary. Specimens such as all these noted I take to be immature examples of *A. austinii*.

Going back still further we have six exceedingly small specimens from Invertiel, which have no radial facets whatever—Fig. 1, Pl. XXIV. The smallest is less than ·7 mm. high. In these the tops of all five R R fit closely in line with the orals above, and my first impression was that we had here another species altogether. The general aspect of these specimens, however, the somewhat coarse character of the surface of the plates (a feature which characterizes this whole group of small specimens), and above all the evidence furnished by the two species *A. scoticus* and *A. elongatus*, to be immediately referred to, compels me to think that *A. austinii* begins as a form without arms, and that these small specimens are the youngest examples of the species in the whole of the material examined. Therefore I take it that in Figs. 1 to 7, Pl. XXIV, we have a more or less transitional series leading up to the adults or mature forms shown on Figs. 8 to 19 on the same Plate. All figures on this Plate (except Fig. 18, which is × 14) are × 11, to give the same scale. The number of arms borne by the large specimens is as follows :—

		Axillary R R.
Fig. 8	7 arms plus anal series	L P R, R A R.
„ 9	5 „ „ „ „	None.
„ 10	5 „ „ „ „	None.
„ 11	7 „ „ „ „	L P R, R A R.
„ 12	7 „ „ „ „	L P R, R A R.
„ 14	8 „ „ „ „	L P R, R A R, Ant. R
„ 15	7 „ „ „ „	L P R , R A R.
„ 16	8 „ „ „ „	L P R, R A R, Ant. R.
„ 19	8 „ „ „ „	L P R , R A R, Ant. R.

The arms seem to have developed sporadically, although in a general way it might be stated that they increased in number with age. This is not always the case, however, as may be seen in both large and small specimens, for example, Fig. 8, Pl. XXIV, is a comparatively small adult and had seven arms. This specimen comes from Howood, a considerable distance from the other localities, but there cannot be any doubt that it belongs to *A. austinii*. Carp. and Eth.'s figs. 1 and 6 on their pl. xv show excellently well the characters of the radial facets in this species, also the inequality in width of the R R. The latter character may further be noticed from the figures given on our Pl. XXIV, from which it may be seen that the L A R is the narrowest R. In all specimens it never bore more than one arm. It must also be stated that the right shoulder of R P R never bore more than one arm.

From what has been said it is clear that the distinctive features of *A. austinii* are: Irregularity in number of arms both in young and adult stages; the possession of an oral arch not, so far as can be seen, pierced by a hydropore; an anal opening into the calyx situated at proximal end of posterior oral and covered in the young by a plate resting on the left shoulder of R P R; in the adult, this plate forms the lowest of a series of arm-like but distinctive plates which are here called the anal series.

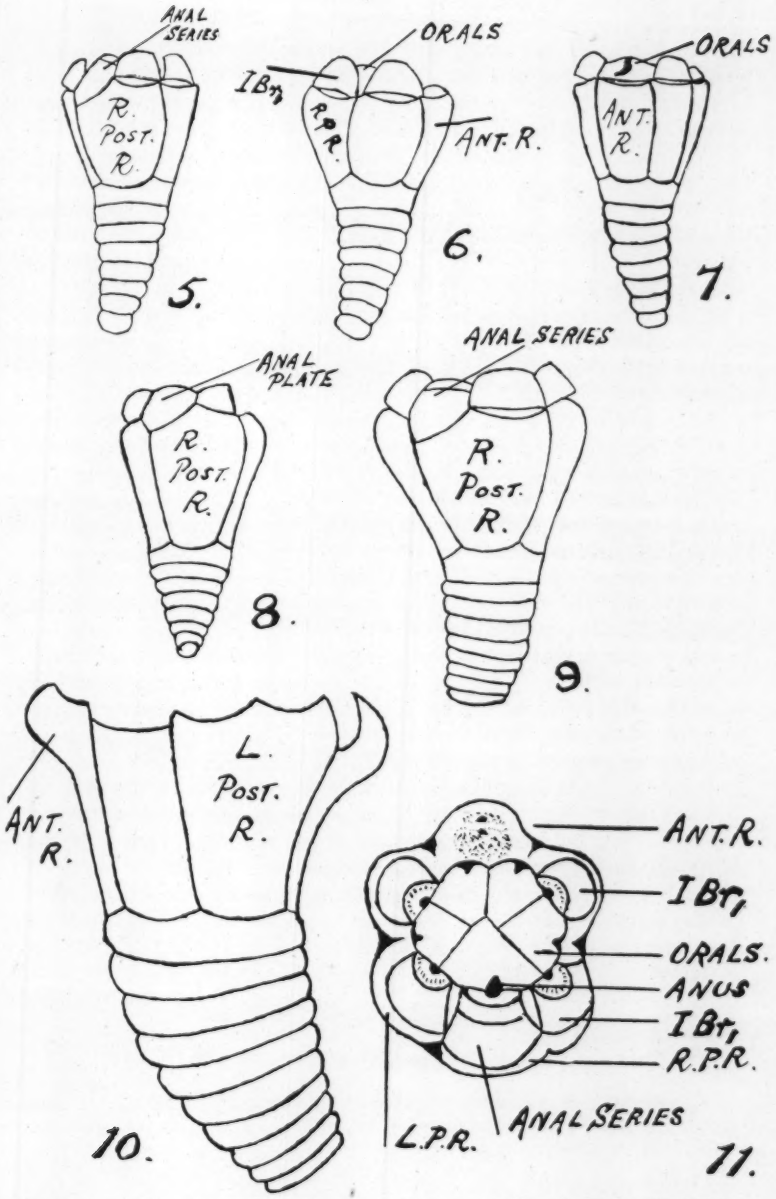
(2) *Allagecrinus garpelensis* sp. nov.

Text-figs. 5 to 11; and Figs. 1 to 13, Pl. XXV.

In the Muirkirk specimens, all of which I place under *A. garpelensis*, we are dealing with a group whose relationship to *A. austinii* is never in doubt. In fact, my first impression was that they were identical with this species. Closer examination, however, shows that they are distinguished by characters which seem to me to warrant their separation as a distinct species and characteristic of the horizon in which they are found. The series shows a somewhat graduated assemblage beginning with a specimen such as that shown on Fig. 6, Pl. XXV, the cup of which, exclusive of the oral arch, measures 1·4 mm. high by 1·8 mm. widest diameter, through a series of larger individuals to that shown on Fig. 13, whose cup is 2·6 mm. high by 4·5 mm. wide. The number of arms borne by these specimens is as follows:—

		Axillary R R.
Fig. 1–3	5 plus anal series	None.
„ 4	5 „ „ „	„
„ 5	5 „ „ „	„
„ 6	5 „ „ „	„
„ 8	5 „ „ „	„
„ 11	5 „ „ „	„
„ 12	6 „ „ „	L P R.
„ 13	9 „ „ „	L P R, Ant. R. (3), R A R.
Others not figured, 7 have	5 „ „ „	No. ax. RR.

Total 15 specimens.



FIGS. 5 to 11.—*Allagecrinus garpelensis*, sp. nov., Garpel Water, Muirkirk. Figs. 5, 6 and 7, side views of a comparatively young specimen. Fig. 11, top view of the same. Figs. 8, 9 and 10, side views of older examples. Figs. 5, 9 and 10, collection of Adam Whyte. Fig. 8, collection of J. Wright. All × 11, except Fig. 11, which is × 17.

Thus, among fifteen specimens of varying sizes, all of "adult" age, thirteen had five arms only; the second largest (Fig. 12) had six, and the largest (Fig. 13) had nine. This constancy to the five-armed character until the crinoid attained a comparatively large size appears to be more characteristic of *A. garpelensis* than it is of *A. austinii*. One of my small Muirkirk specimens is rather less in height than the smallest on Pl. XXV. It has a great resemblance to, in fact is scarcely distinguishable from, the young forms of *A. austinii* figured on Pl. XXIV, Figs. 1 to 7. It is somewhat badly crushed, but it seems to me that this specimen had only four of the R R developed as in Fig. 41, Pl. XXIII.

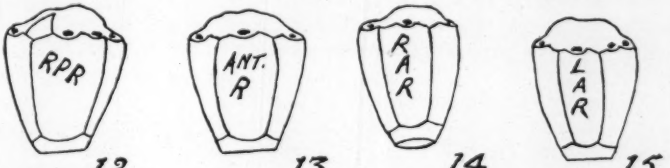
A characteristic feature of this group of specimens from Muirkirk, as compared with *A. austinii*, is that the plates of the calyx get relatively thicker with age until they culminate in a form like that shown in Fig. 13, Pl. XXV, where the R R at the top are much swollen and the whole calyx has a ponderous and heavy appearance. (This specimen has three arm-bearing radial facets on Ant. R.) In medium-sized examples we see this tendency to heaviness and curving over of the R R at the top particularly well—Figs. 5 and 11, Pl. XXV. Such features are probably of a gerontic nature, when we consider the high horizon in the Carboniferous Limestone Series in which the specimens are found. The characters of the stem are excellently shown in the Muirkirk specimens, and may be noted from the figures on Pl. XXV. It is generally curved away from the anterior side of the calyx, and in the larger specimens consists of ten or more columnals. Correlated with the heaviness of the plates of the calyx is the fact that the plates themselves have a somewhat coarser ornamentation than in *A. austinii*. In the latter species, the plates in the young are of an extremely porous nature. This becomes more markedly granular in older examples until in the largest it is represented by a very fine tuberculation or in some specimens almost a smooth surface. For all these reasons, together with the fact that the Muirkirk specimens come from a horizon so much higher than the typical *A. austinii*, it seems advisable to give them another name. With further research such distinctive specimens may help to mark the position of the West of Scotland bed in other parts of the country.

(3) *Allagecrinus biplex*, sp. nov.

Text-figs. 12 to 15; and Figs. 35 to 38, Pl. XXIII.

The number of specimens referred to this species is twelve. Of these three are from Invertiel and nine from Carlops, all in my collection. They are fairly uniform in size, a good average being 1·5 mm. high over the calyx, by 1 mm. at widest across outer edges of R R and narrowest diameter ·7 mm. The narrowest diameter is from posterior to anterior, and widest from L A R to R A R. The specimens therefore have the appearance of being compressed. The Ant. R is a

fairly wide plate, so also are the L P R and R P R, but R A R and L A R are much narrower, the L A R having the least width. The R P R is distinguished by the fact that its left shoulder slopes down somewhat steeply and meets the right shoulder of the L P R. The latter does not slope quite so steeply. The result is we have a notch which is occupied by a long tapering plate. The general appearance of this plate may be noted from Text-fig. 12. It is the anal plate and it bends over on to the calyx and closes the anal opening.[1] In specimens



FIGS. 12 to 15.—*Allagecrinus biplex*, sp. nov. from Carlops. Side views of one of the type specimens. J. Wright collection. × 17.

in which this plate is absent the position of the anus can be seen. It is situated at the proximal end of the posterior oral as in *A. austinii* and *A. garpelensis*. The oral arch in this species is comparatively low. All the specimens bear in miniature form a striking resemblance to the mature *A. austinii*. Their plates are smooth or nearly so, but the distinguishing character in which they differ from *A. austinii* and all the other species under consideration is that the right shoulder of R P R always has two arm-bearing radial facets, the left shoulder being occupied by the aforesaid anal plate. Details of the other R R are given under "Summary of Species", further on. Here, again, the L A R is the narrowest plate, and never bore more than one arm. I have not found any very small specimens which can be looked upon as the young, nor have I found any larger than about 1·6 mm. in height, which could be taken as transitional to the "adult" *A. austinii*. I therefore look upon these specimens as mature examples of a distinct species, to which I give the name *A. biplex*.

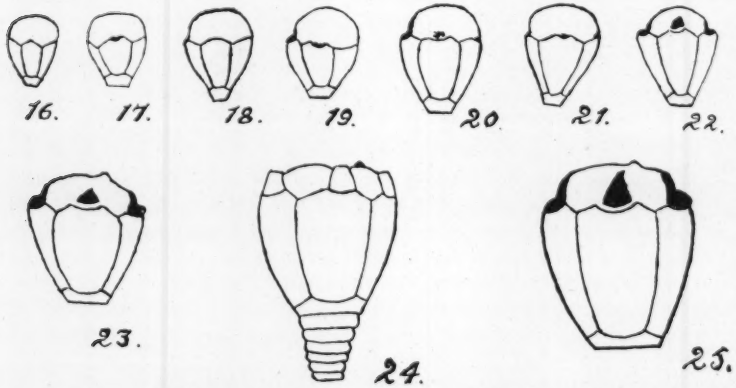
(4) *Allagecrinus scoticus*, sp. nov.

Text-figs. 16 to 25; and Figs. 1 to 17, Pl. XXIII.

Among the whole of the material by far the most abundant is the one I now call *A. scoticus*, The number of specimens from Invertiel

[1] I have tried to determine whether there are two plates here—an upper and lower—but cannot see any suture line. Although invisible, it is probable that there is a suture about the middle of the long anal plate shown on Text-fig. 12. Since studying these specimens, I have found another calyx which shows that in some cases at least there were two anal plates, a lower, somewhat broad plate, and an upper tapering one. The specimen in question has only the lower plate in position with the joint surface for the upper plate clearly visible.

is 813 out of a total of 869 from this locality, and 100 from Carlops from a total of 110. These specimens are of all sizes, the smallest being about ·5 mm. in height and ·4 mm. in diameter, and the largest 1·5 mm. in height by 1·3 mm. in diameter. They begin with some very small examples among which may be noticed a few without arm-bearing radial facets. When these calices are looked at from above it is observed that the top of each radial fits almost in line with the overlying oral and no radial facets are yet developed. These particular examples, of which there are nine, are not to be confused with the six very small individuals of *A. austinii* already noted, nor are they to be confused with similar sized non-arm-bearing young of *A. elongatus*, to be immediately referred to. They



FIGS. 16 to 25.—*Allagecrinus scoticus*, sp. nov. Figs. 16 to 22, side views of young examples, showing sporadic development of radial facets, all from Invertiel. Figs. 23, 24, and 25, mature specimens. Fig. 24 shows the IBr_1 in position. Fig. 23 from Invertiel, 24 and 25 from Carlops. All in collection of J. Wright. × 17. Compare with Plate XXIII.

are much rounder in outline and have the fine granular or frosted surfaces of the larger specimens of *A. scoticus*. Very little larger than these may be noted others which have only one radial facet developed, the top of the other R R may be in line with the orals or may show as mere slits with, so far as can be seen, no trace of the axial canal. Others, again, somewhat larger, may be noted with two, three, or four radial facets only developed, the undeveloped radial facets showing as mere slits or not at all; or in others one may find the tops of all five R R projecting beyond the line of the orals, but with the radial facets scarcely visible, and in such cases I hardly think any arms were yet borne by them, since I cannot see any trace of axial canal or cross ridge. In other cases similar sized specimens undoubtedly bore arms on all R R since these processes on the facets can be seen, the facets in these cases being well developed. It seems, therefore that the development of the facets

took place sporadically and not according to any rule. The structure of the facets, in this species as well as in the following species, *A. elongatus*, apparently are of the same general plan as those of *A. austinii*, although one has to confess that it is often difficult if not impossible to define such structures in the extremely small specimens. Further details of the smaller specimens are given on p. 357, and I think it cannot be doubted that *A. scoticus* began as a form without arms, just as in the case of *A. austinii*. On Carp. and Eth.'s pl. xvi similar specimens are probably represented by their figs. 2, 4, 5, 6, and 7. Their fig. 7 represents what I take to be a nearly full-grown individual of *A. scoticus*.[1] I have sorted out all the larger individuals of the species. A good average size is 1·3 mm. high by about 1 mm. widest diameter across from edge to edge of R R. The largest examples are from Carlops, and measure 1·5 mm. high by 1·3 mm. wide. Among the Invertiel material there are sixty-three specimens below ·9 mm. high by ·7 mm. wide. Details of these are given on p. 357, and a typical series are shown on Text-figs. 16 to 22, and Figs. 1 to 12 on Pl. XXIII. It will be observed that among this group of small specimens some have the R R already well developed; the majority, however, have immature radial facets. All the larger specimens, above ·9 mm. high, always have all five R R well developed, and these I take as the mature examples of *A. scoticus*, Text-figs. 23, 24, 25, and Figs. 13, 14, 15, 16, and 17, Pl. XXIII. I cannot see how it is feasible to link up such specimens with *A. austinii*, as was done by Carp. and Eth. They have all the characters of a distinct species: (1) The possession of a little knob which is situated towards the distal end of the posterior oral. I take this to be a hydropore since in the better-preserved specimens I can detect an exceedingly minute aperture at the end of the knob.[2] The knob itself is usually prominent on all the larger well-preserved specimens, but difficult and sometimes impossible to see in the smaller examples. It can be seen on Figs. 14, 15, 16, and 17, Pl. XXIII. (2) The R P R is not differentiated and there is no trace of an anal plate or anal opening as such. (3) The equal width of all the R R. (4) The constant five-armed character of all the specimens on reaching maturity, none of the R R being axillary. All these characters are in contrast to those of *A. austinii* and, indeed, they raise the question whether it is correct to place these specimens under *Allagecrinus*. This matter is referred to later.

Among the whole of the material grouped under *A. scoticus*, as well as under the following species, *A. elongatus*, I have only found one example of the former with part of the stem in place and three of the primibrachs in position. The specimen is figured on Pl. XXIII

[1] Compare with our Plate XXIII, Figs. 14, 15, 16, and 17.

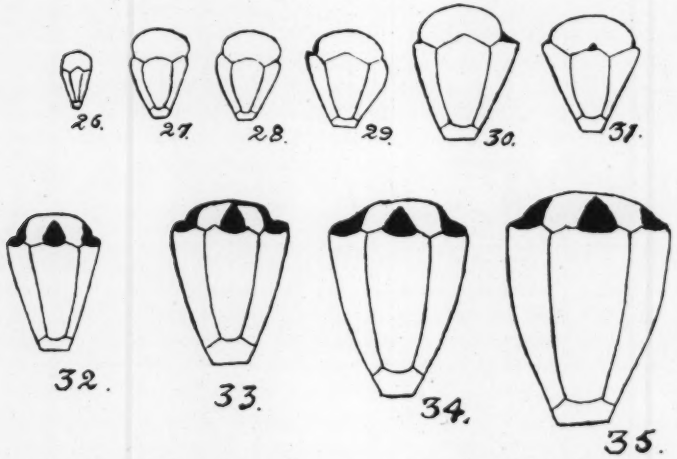
[2] Dr. Bather has interpreted the pore in *Haplocrinus* and *Allagecrinus* as ? anus + hydropore, but Professor Wanner now thinks from the study of his Timor *Allagecrini* that the pore subserved one function only, i.e. hydropore, and that the orals had the power of opening themselves to a certain degree.

Fig. 13, and a sketch from it on Text-fig. 24. The stem is slightly displaced. It consists of six columnals, but there are several more missing. Probably it tapered to a point, as in *A. austinii* and *A. garpelensis*.

(5) *Allagecrinus elongatus*, sp. nov.

Text-figs. 26 to 35; Figs. 18 to 34, Pl. XXIII.

Another group of specimens now falls to be noticed. They number forty from Invertiel in my collection, and sixty-eight from the West of Scotland in Mr. J. Smith's collection. These I name *A. elongatus*. They are specially distinguished from *A. scoticus* by the fact that they are always elongated or pyriform in shape, and probably their most striking character is the irregular number of arms borne by



FIGS. 26 to 35.—*Allagecrinus elongatus*, sp. nov. Figs. 26 to 31, immature examples from Howood in J. Smith collection. × 17. Figs. 32 to 35, mature specimens. × 20. Figs. 32 and 34 in J. Smith collection from Howood. Figs. 33 and 35 in J. Wright collection from Invertiel.

the R R by specimens of all sizes. They are also distinguished by having their plates deeply pitted or honeycombed in contrast to *A. scoticus*, whose plates under the microscope are at most frosted in appearance. In the hollow of the posterior oral can often be detected a hydropore. It is sometimes in the form of a knob as in *A. scoticus*, but when it occurs as such, it does not project above the line of the orals. In other cases it shows as a flattened excrescence which helps to distinguish the posterior oral. The posterior oral is sometimes to be distinguished by its somewhat larger size. This also is the case with *A. scoticus*. As far as I can see, there is no trace of anal plate as such, nor is the R P R differentiated. The R R

appear to be about equal in width, although in such small specimens it is difficult to measure them accurately. The basal ring in this species is relatively higher than it is in *A. scoticus*, whose basal circlet is very low. The oral arch in *A. elongatus* is generally low in height or even flattened in contrast to that of *A. scoticus*, which is high and usually in the form of a dome. In *A. elongatus* one can also trace the larger specimens back to very small forms with undeveloped RR and ultimately to a few examples without radial facets at all, (Figs. 18 to 25, 28, and 29, Pl. XXIII). The best preserved of these are in J. Smith's collection. As in the case of the very small specimens without arms, which I place under *A. austinii* and *A. scoticus*, I cannot but think that these also are the young of *A. elongatus*. They have always deeply honeycombed or porous plates, even in the exceedingly small specimen shown on Fig. 19, Pl. XXIII. This specimen is less than ·4 mm. in height, and about ·2 mm. in widest diameter. On the finer preserved examples also can be seen the hydropore on posterior oral. There are several of these small non-armed specimens, some of which are larger, and one might think we had here a distinct species. When some of these specimens are looked at from the top, however, it is noticed that the R R near their junction with the orals swell out and the outer lips of the R R project slightly beyond the line of the orals (Figs. 20 and 22, Pl. XXIII). Alongside are others like Text-fig. 28, and Figs. 18 and 21, Pl. XXIII, where the radial facets seem to be breaking through or opening out, but it does not appear that they yet bore arms. On such specimens as those shown on Figs. 25 and 28, Pl. XXIII, it is difficult to say whether the radial facets were in a condition to bear arms, as I am unable to see any trace of axial canal or cross-ridge, although there is certainly a gap between the inter-oral sutures and the inner edges of the radials. There are, however, other specimens, some smaller, others larger (Text-figs. 29 and 30, and Figs. 23, 24, and 29 Pl. XXIII), where one or two radial facets are distinctly developed. If one turns such a specimen as Fig. 23, Pl. XXIII, which has only two R facets developed, with the developed facets to the rear, it is indistinguishable from such a form as Fig. 18 on the same plate, where none of the radial facets are developed. Other specimens may show one radial facet well developed, with the others only opening out in varying degrees. These immature examples, of which there are thirty-nine out of a total of 108 dealt with, are all below 1 mm. in height. The oral arch is relatively high in the youngest individuals, but with age, as more facets (or arms) are developed, it tends to flatten out. Details of the specimens are given on p. 359. The general form, etc., of the mature examples is shown on Text-figs. 32, 33, 34, and 35, and on Figs. 31, 32, 33, and 34 on Pl. XXIII. Here, again, as in *A. austinii* and *A. scoticus*, one is forced to the conclusion that *A. elongatus* developed from a non-armed form. In fine, I believe that we have among the whole of the material undoubted evidence that the three species, viz. *A. austinii*, *A. scoticus*, and

A. elongatus, began as non-armed forms, which can be easily distinguished from one another by their special characteristics and which in each case lead us through a more or less well-defined transitional series to the mature form. The chief characters of *A. elongatus*, except perhaps in the irregularity in number of arms, are such that we cannot regard the specimens as the young of *A. austinii*. As with *A. scoticus*, they are distinctive enough to warrant another name. The species is probably represented on Carp. and Eth.'s plate xvi by figs. 1, 3, and 10.

THE "IMMATURE" SPECIMENS OF CARP. AND ETH.'S PL. XVI.

After the foregoing pages were written, Dr. J. Pringle was good enough to allow me to examine the "young" or "immature" specimens figured by Carp and Eth. on their pl. xvi. These specimens are preserved in the Geological Survey Collection in the Royal Scottish Museum in Edinburgh, and are mounted on tablets along with the three "adults" which I had before studied. They confirm in a most satisfactory way the conclusions already given. It is a matter of some difficulty, however, to fix on all the actual figured specimens as since Carp. and Eth.'s time it is obvious that the specimens have been remounted. A few have been displaced, and one or two are missing. I have been able to make out the following. On tablet No. 1610 is probably the original of fig. 7, and on No. 1611 the original of fig. 5. The top drawings of these, figs. 7*b* and 5, are not quite satisfactory, but both are typical examples of *A. scoticus*, and I select fig. 7 as the holotype with paratypes as indicated on another page. Fig. 7 is about the same size as our Fig. 14 on Pl. XXIII. Figs. 2 and 4 are also recognizable. Fig. 2 is on tablet No. 1618, on which there are three specimens of *A. scoticus*, and fig. 4 is probably on the same tablet, along with another mature specimen. Fig. 6 I am not quite certain about, although it is probably among the specimens, and it is quite evident from these that *A. scoticus* is represented on the plate by figs. 2, 4, 5, 6, and 7. As to *A. elongatus*, fig. 1 is mounted on 1604, and is a typical immature form of the species. Fig. 3 is probably the same, as I notice one or two specimens very like it. There is some dubiety about figs. 8 and 10. Tablet 1619 has "Pl. xvi, f. 9" written on it, but there are three typical specimens of *A. elongatus* mounted on the tablet, and there has been a fourth which is now missing. The largest of these three is the likeliest, but it does not correspond with fig. 9, which is a different species and noted below. The top of the large specimen on 1619 is somewhat worn, and is difficult to see clearly, but its structure is certainly not that as given on fig. 9*a*. I therefore take one of the better preserved specimens as holotype of *A. elongatus*, and fix on one mounted on tablet No. 1603. From the side, C. and A.'s fig. 10*a* might be taken for it, but when viewed from the top No. 1603 shows three axillary R R, the R P R, R A R, and L A R, and not five single arm-bearing facets as fig. 10*b*. Figs. 10*a* and 10*b*

are, of course, quite typical of *A. elongatus*, but I cannot trace the specimen. As regards fig. 9, this is a young specimen of *A. austinii*, and is mounted on tablet No. 1605, which also has $\frac{B}{9}$ and the number 5036 at the corner. This specimen has only three radial facets developed, the R P R, R A R, and L A R, the other two R R being in line with the orals. The position of the anal opening can be seen. Although rather smaller, the top of this specimen closely resembles that of our Fig. 3 or 4, Pl. XXIV. In the drawing on fig. 9*a* of C. and A.'s pl. xvi one radial can be seen joined up with overlying oral. The top drawing on fig. 9*b* is, however, not good, as Carp. and Eth. missed the significance of the anal opening and here it is not shown.

To sum up, figs. 2, 4, 5, 6, and 7 on Carp. and Eth.'s pl. xvi are undoubtedly specimens of *A. scoticus*, and figs. 1, probably 3, and 10 belong to *A. elongatus*. Fig. 9 is a young specimen of *A. austinii*. Fig. 8 is doubtful, as I cannot recognize it among the specimens. The specimen on pl. xv, fig. 7*a*, is also not among the specimens. It is the "intermediate" example of Carp. and Eth. It is stated to come from Carluke, and it is possible it is a young form of *A. garpelensis*.

Summary and Details of Species.

(1) *Allagecrinus austinii* Carpenter and Etheridge.

Annals and Mag. Nat. Hist., **5**, vii, April, 1881, pl. xv, figs. 1, 2, and 6.

Description.—A small monocyclic crinoid which has a basal ring with no sutures visible; five R R with prominent sutures. R R unequal in width, the L A R being the narrowest and only bearing one arm. The wider R R may be axillary. In the adult the number of arms varies from five to ten. Oral arch prominent, consisting of five O of nearly equal size, the post. O being the largest. Arch tends to become detached in older specimens. Anal opening on ventral surface, situated at prox. end of post. O and protected by a series of arm-like plates which rise from left shoulder of R P R. R P R differentiated, the sloping left shoulder lying well below the level of L P R. Right shoulder of R P R not axillary, and only bore one arm. In young stages begins as a form without arms. Later, two, three, or four single arm-bearing facets may develop. The first anal plate or differentiation of R P R usually visible in young stages. Plates of oral arch and calyx deeply pitted; this gradually disappears with age, until in the older forms it is represented by a fine granular ornamentation. In very mature examples plates are smooth. Stem vermiform, consisting in the adult of ten or more columnals.

Syntypes.—In collection of Scottish Geological Survey, numbered 1602 and 1608*a* and *b*, originals of Carp. and Eth.'s figs. 1, 2, and 6,

pl. xv (Figs. 14, 14*a*, 15, 16, 17, and 18, Pl. XXIV, and Text-figs. 1–4 of present paper).

Paratypes.—In collection of Geological Survey, tablet No. 1605. In collection of J. Wright, Nos. A 9, A 10, A 11, A 12, and A 19. In J. Smith collection (Geol. Survey, Edinburgh), No. A 8.

Localities.—No. 1 Bed, Invertiel; Carlops; Howood. Lower Carboniferous Limestone Series.

Measurements.—

Smallest specimen measures	.	·7	mm.	high by	·6	mm.	wide.		
Fig. 2 Pl. XXIV	„	. 1·3	„	„	„ ·9	„	„	× ·7	mm.
„ 3 „ XXIV	„	. 1·6	„	„	„ 1·3	„	„	× 1·2	mm.
Largest specimen, Fig. 19, Pl. XXIV, measures	. .	2·4	„	„	„ 3	„	„		

(2) *Allagecrinus garpelensis*, sp. nov.

Description.—A small crinoid, similar in size to *A. austinii*. The specimens show a graduated series from comparatively young up to the most mature form represented by Text-figs. 5–11 and Figs. 1–13, Pl. XXV. Arms in this species are also variable in number. In the younger examples they always number five, and range up to nine in the older forms. R R much swollen at their upper margins, especially in medium-sized and the older specimens. This is the specially distinguishing feature of this species compared with *A. austinii*. Oral arch well preserved in the smaller and medium-sized specimens, and anal opening well seen at prox. edge of post. oral. R P R differentiated, the left shoulder of this plate lying well below the level of adjoining R, and supports an arm-like series of anal plates, the grooved interior of which leads down to the anus.

Syntypes.—In collection of Adam Whyte, Nos. M 1, M 8, M 12, and M 13. J. Smith collection, Nos. M 7. J. Wright collection, M 4.

Locality.—Garpel Water, Muirkirk; below the Blue Tour Limestone, Upper Carboniferous Limestone Series.

Measurements.—

Cup of smallest specimen, Fig. 6, Pl. XXV, 1·4 mm. high by 1·8 mm. wide.
„ „ Fig. 8, 1·6 mm. high by 2·6 mm. wide.
„ „ „ 11, 1·8 mm. high by 2·8 mm. wide.
„ „ „ 13, 2·6 mm. high by 4·5 mm. wide.

(3) *Allagecrinus biplex*, sp. nov.

Description.—A minute crinoid with unequal R R. Specimens range from 1 mm. in height by ·8 mm. widest diameter by ·7 mm. narrowest diameter to 1·5 mm. in height by 1 mm. by ·7 mm. Very similar in appearance to the adult specimens of *A. austinii*, but distinguished from it by the R P R always having two single arm-bearing facets, in addition to an anal plate on its left shoulder. Oral arch low in height; anal plate bends over on calyx and covers the anal opening. Surface of plates smooth.

Syntypes.—In collection of J. Wright, Nos. A 35 and A 35*a* from Carlops.

Localities.—No. 1 Bed, Invertiel; Carlops. Lower Carboniferous Limestone Series.

Details of Specimens.—

INVERTIEL.

1 specimen has 3 Axillary R R	. R P R, L P R, and Ant. R, others single.
1 „ „ 1 „ „	. R P R.
1 „ „ 2 „ „	. R P R and L P R, others single.

CARLOPS.

5 specimens have 2 Axillary R R	. R P R and L P R, others single.
3 „ „ 1 „ „	. R P R, others single.
1 „ has 2 „ „	. R P R and Ant. R, others single.
Largest specimen from Invertiel	. 1·4 mm. × ·9 mm. × ·8 mm.
Smallest „ „ „	. 1 mm. × ·8 mm. × ·7 mm.
Largest „ „ Carlops	. 1·5 mm. × 1 mm. × ·7 mm.

(4) *Allagecrinus scoticus*, sp. nov.

Description.—A minute species, ranging in size from ·5 mm. in height by about ·4 mm. wide, to 1·5 mm. in height by 1·3 mm. wide. Surfaces of plates finely granulated or frosted; calyx always globose or sub-globose. Oral arch generally high, with hydropore situated well up towards the distal end of post. oral. In profile this hydropore usually projects above the line of oral arch. In the mature stages, arms always five in number. R P R not differentiated. Suture lines between R R can usually be detected, also the lines between R R and B B, but the divisions, if any, between B B cannot be made out. Suture lines between orals can in most cases be seen. R R equal in width. The finely granulated or frosted surface of the plates is characteristic of this species in specimens of all sizes, and serves as a guide to distinguish it from *A. elongatus*. Begins as a form without arms. In the young radial facets develop sporadically. Stem probably vermiform. Basal ring very low.

Holotype.—In collection of Scottish Geological Survey, tablet No. 1610.

Paratypes.—In collection of Scottish Geological Survey, tablets Nos. 1611 and 1618. In J. Wright collection, Nos. C 1 to C 17.

Localities.—No. 1 Bed, Invertiel; Cowdens; Roscobie; Carlops; Skateraw, Dunbar; Ponniel Water, Lesmahagow. Lower Carboniferous Limestone Series.

DETAILS.

SMALL IMMATURE SPECIMENS FROM INVERTIEL.

9 with no R facets developed.
1 with L P R facet developed, L P R partly so, Ant. R and L A R mere slits with tops of R R almost in line with orals.
1 with R P R and Ant. R facets developed, R A R faintly so, other R R almost in line with orals.
1 with R P R, Ant. R, and L A R well developed, L P R faintly so, R A R just a slit.
1 with R P R and L A R facets well developed, R A R and L P R faintly so, Ant. R without arm.

1 with R P R, L A R, and R A R facets well developed, Ant. R and L P R not developed.
1 with 4 well-developed R facets, the fifth (L P R) not so well developed but distinctly seen.
1 with 4 well-developed R facets, the fifth (R P R) not developed. In this specimen the first brachial is in position on 2 of the R R.
1 with 1 R facet developed, all the others not developed, position uncertain.
1 with very small specimen Ant. R facet developed, all the others mere slits.
1 with 4 fairly well-developed R facets, the other (L P R) just a slit.
1 with 2 R facets only developed, R P R and L A R.
1 with 1 R facet only developed, other R R in line with orals.
3 with all 5 R facets well developed.
1 with all 5 R facets feebly developed.
1 with 4 R facets fairly well developed, L P R no facet.
1 with 2 R facets only developed, position uncertain, other R R in line with orals.
1 with 2 R facets only developed, position uncertain.
1 with 1 R facet well developed, 2 fairly well, other 2 not developed.
1 with 1 R facet well developed, 2 show as slits, 2 in line with orals.
1 with 3 well-developed R facets, 2 show as slits.
1 with 3 well-developed R facets, 1 fairly well, 1 with no facet.
1 with 5 well-developed R facets.
1 with 3 well-developed R facets, 2 show as slits.
1 with 3 well-developed R facets, 2 partly developed.
1 with 2 well-developed R facets, 3 partly developed.
1 with 3 well-developed R facets, 2 not developed, in line with orals.
1 with 4 well-developed R facets, 1 faintly developed.
3 with 3 well-developed R facets, 2 partly developed.
1 with 3 well-developed R facets, 3 not developed, in line with orals.
2 with 2 well-developed R facets, 3 show as slits.
1 with 1 well-developed R facet, others not developed, although 1 projects slightly beyond line of orals.
1 with R P R and L A R facets well developed. L P R and Ant. R show as slits, R A R in line with orals.
1 with R A R and L A R facets well developed, L P R a slit, R P R and Ant. R in line with orals.
1 with 4 R facets well developed, Ant. R no facet.
1 with 2 R facets well developed. 1 partly so, 2 no facets.
1 with 4 R facets well developed, the other in line with orals.
2 with 2 R facets well developed, the other 3 no facets.
1 with 4 R facets well developed, the fifth (R P R) only partly developed.
3 with the tops of all 5 R R showing only as slits.
1 with R P R facet well developed, R A R and Ant. R poorly so, others in line with orals.
1 with 3 R facets well developed, R P R and R A R no arm facets in line with orals.
2 with 5 R facets well developed.
1 with 3 R facets well developed, R P R and R A R in line with orals.
1 with 3 R facets well developed, 2 in line with orals.
1 with 3 R facets well developed, 1 in line with orals, the other shows as a slit.

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Measurements.

Smallest of above	.	.	.	·5 mm. high.
Largest ,, ,,	.	.	.	·9 ,, ,,
Smallest with all 5 R facets well developed				·6 ,, ,,
Largest ,, ,, ,, ,,				1·5 ,, ,,

All specimens above ·9 mm. high have always the 5 R facets well developed.

(5) *Allagecrinus elongatus*, sp. nov.

Description.—A minute species, ranging in size from ·3 mm. or ·4 mm. in height by ·2 mm. diameter to 1·7 mm. in height by 1 mm. diameter. Plates of this species are always deeply pitted or honeycombed. Calyx more or less pyriform or elongated in contrast to the previous species. Oral arch low with hydropore situated in the concave depression of post. oral, towards the distal end. Hydropore does not project above the line of oral arch. Variable number of arms. In adult specimens may be six or eight. Develops from a form without arms. In young and even moderate-sized specimens arms seem to develop sporadically. R P R not differentiated. Basal ring higher than in *A. scoticus*.

Holotype.—In Scottish Geological Survey collection, tablet No. 1603.

Paratypes.—In Scottish Geological Survey Collection, tablet No. 1604. In J. Smith collection (Geol. Survey), Nos. C 19 to C 30, from Howood. In J. Wright collection, Nos. C 31 to C 34, from No. 1 Bed, Invertiel.

Localities.—No. 1 Bed, Invertiel; Laddedie; Howood; Auchenmade; Midton; Ponniel Water, Draffen; Lesmahagow; Dalry; Skateraw, Dunbar. Lower Carboniferous Limestone Series.

DETAILS.

Specimens from Invertiel, J. Wright Collection.

Height 1 mm. to 1·7 mm. Mature specimens.

1 with 3 axillary R R—L P R, R P R, R A R, others single.
3 „ 1 „ „ probably R A R, others single.
4 „ 1 „ „ L P R, others single.
6 „ 2 „ „ L P R, R A R, others single.
4 „ no „ „ all 5 R R bearing, 1 arm only.
4 probably the same, but difficult to see.
2 with 1 axillary R R, position uncertain.
2 „ 2 „ „ „ „

Height ·6 mm. to 1 mm. Immature specimens.

2 with 4 single arm-bearing facets only, the other (position uncertain) in line with orals and no facet developed.
3 with 3 single arm-bearing facets only, the other R facets not developed, top of R R being in line with orals.
1 with 3 single arm-bearing facets, 1 axillary R, the other no facet developed, positions uncertain.
1 with no arm facets developed, smallest specimen, ·6 mm. high.
7 somewhat crushed specimens; no data.

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Specimens from Howood and Glenfield, J. Smith Collection.

Height from ·3 mm. to ·7 mm. Immature specimens.

7 specimens with no radial facets developed, but in the larger, tops of R R bulge out and junction of R R with O seems opening out.

Height from ·6 mm. to 1 mm.

5 (* 2) specimens with 5 single arm-bearing facets well developed.
1 with 2 single arm-bearing facets only developed, others not developed. ·7 mm. high.

1 with 2 R facets well developed, probably L P R and Ant., others not developed. ·8 mm. high.
1 with 2 R facets well developed, L P R and L A R, others not developed. ·7 mm. high.
1 with 2 R facets well developed, R P R and L A R, R A R feebly developed, other 2 not developed. ·8 mm. high.
1 with 3 R facets developed, R P R, R A R, and L A R, other 2 not developed. ·8 mm. high.
1 (* 1) with 4 R facets well developed, the fifth poorly developed, position uncertain. ·9 mm.
1 with 1 R facet poorly developed, the others even less so. ·8 mm. high.
1 with 3 R facets well developed, other 2 poorly developed. ·8 mm. high.
1 with L A R facet well developed, other R R not developed. ·7 mm. high.
1 with 1 R facet well developed, the other 4 feebly developed. ·9 mm. high.
1 with all 5 R R bulging at top, but apparently no facets developed. ·8 mm. high.
1 with all 5 R facets feebly developed. ·8 mm. high.
1 with R P R, L A R, and R A R well developed, others poorly. 1 mm. high.
2 uncertain. ·8 mm. high.

Height from 1 mm. to 1·7 mm. Mature specimens.

3 (* 1) with no axillary R R. All 5 facets well developed.
1 with 3 axillary RR. L P R, R A R, and Ant. R, others single.
5 „ 1 „ „ L P R, others single.
1 „ 1 „ „ R P R, others single.
7 (* 3) with 2 axillary R R. L P R, R A R, others single.
1 with 1 axillary R R. L P R, others single.
1 „ 1 „ „ This axillary R has 3 arm-bearing facets. Position uncertain. Others single.
1 „ 2 „ „ Others single.
5 no data.

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All are from Howood, except 7 from Glenfield, marked in brackets with *, the figure referring to number of specimens.

Auchenmade.

1 with 2 R facets well developed, others not developed. ·8 mm. high.
1 with 1 R facet well developed, 1 feebly developed, the others in line with orals. ·8 mm. high.

Midton.

1 with 1 axillary R, others single. 1·1 mm. high.

Ponniel Water.

1 with no R facets. ·3 mm. high.
1 „ „ „ but top of R R bulging out. ·4 mm. high.
1 „ all 5 R facets developed. ·7 mm. high.
1 „ „ „ „ ·6 mm. high.
1 „ „ „ „ 1 mm. high.

Dalry.

1 with all 5 R facets apparently developed. ·5 mm. high.

Skateraw, Dunbar.

1 with 3 R facets not developed, but bulging at top and where they join orals show as slits; the other 2 R facets not developed. ·5 mm. high.
1 with no R facets developed, bulging at top. ·4 mm. high.
1 with 3 R facets developed, others not developed. ·5 mm. high.

DRAFFEN, LESMAHAGOW.

1 with 1 R facet well developed, others feebly. ·7 mm.

LADDEDIE, FIFE.

1 with no R facets developed. ·3 mm. high.
2 with 2 axillary R R, positions uncertain, others single. 1·1 mm. high.

DISTRIBUTION OF SPECIES.

Allagecrinus austinii.—Occurs in Lower Carboniferous Limestone Series, in East and West Scotland.

Allagecrinus garpelensis.—Occurs below the Blue Tour Limestone, Upper Carboniferous Limestone Series, in West of Scotland.

Allagecrinus biplex.—Occurs in Lower Carboniferous Limestone Series in East of Scotland.

Allagecrinus scoticus.—Occurs abundantly in the Lower Carboniferous Limestone Series of the East of Scotland. Only three specimens recorded from the same horizon in West of Scotland.

Allagecrinus elongatus.—Occurs frequently in the Lower Carboniferous Limestone Series of the East of Scotland; also in Lower Carboniferous Limestone Series of West of Scotland.

There are two interesting points about the distribution of the specimens dealt with in this paper: (1) *A. scoticus*, which is exceedingly abundant at Invertiel and Carlops, is only represented by three specimens from the West of Scotland; and (2) *A. elongatus*, which is of frequent occurrence at Invertiel and in the West of Scotland, at Howood, is not represented by a single individual from Carlops, where *A. scoticus* is abundant, and where *A. austinii* is found.

CONCLUSION.

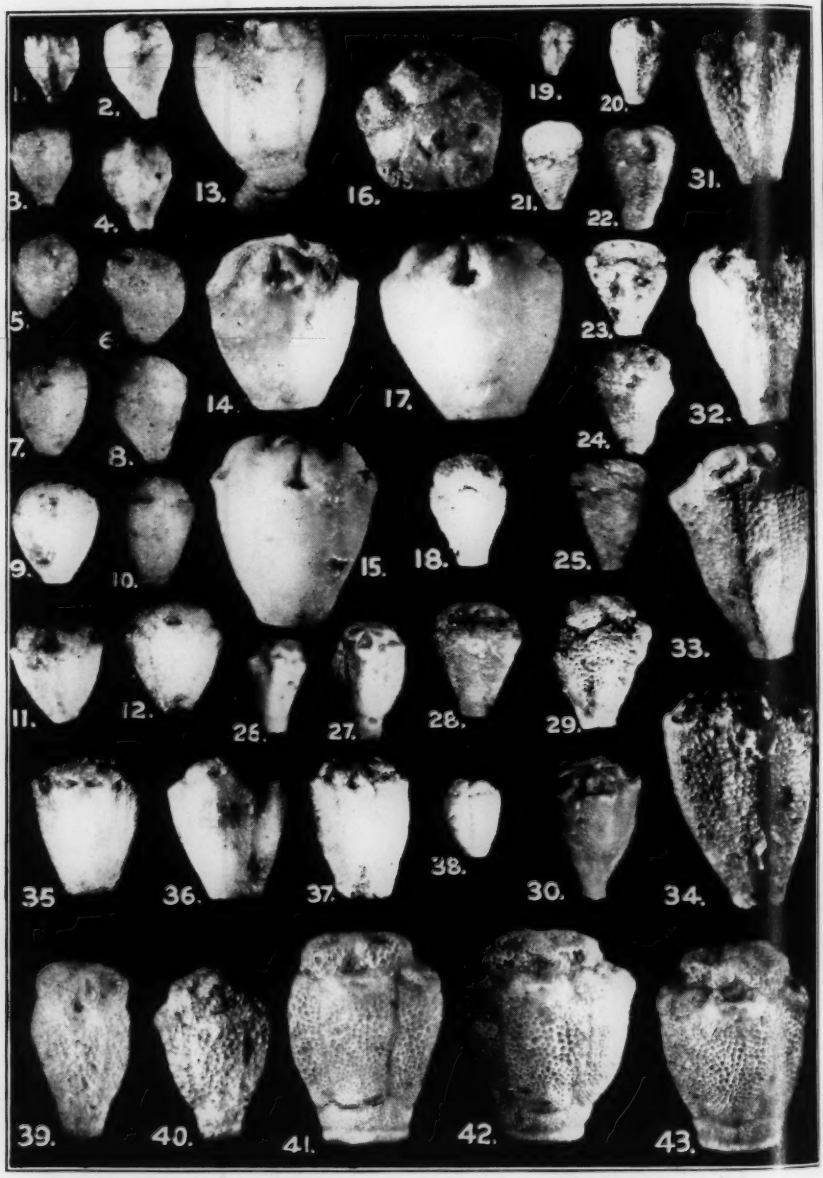
In this paper I have tried as far as possible to give an idea of the different types of specimens with which I have had to deal. There cannot be much doubt, I think, that in the five species here described, and particularly in *A. austinii*, *A. scoticus*, and *A. elongatus*, we see in varying degrees different stages in the development of these small "larviform" crinoids. Carpenter and Etheridge had such ideas in mind when considering how to regard the small forms among the material at their disposal. I am satisfied, however, that they were wrong in thinking that all their small specimens were the young of their species *A. austinii*. Their fig. 9 on pl. xvi is the only specimen which on the evidence herein adduced can be referred to with certainty as a young individual of their species. All the others on this plate, as already indicated, except fig. 8, which I cannot trace, I put down to *A. scoticus* or to *A. elongatus*.

Carp. and Eth. were also mistaken in thinking that their "adult" type specimen, fig. 2 of their pl. xv, possessed no oral arch. This was simply because they did not clean down between the brachials. They, of course, admit that the absence of an oral arch from all three "adults" did not necessarily prove that this structure was

not present during life, but their failure to find the arch in their fig. 2, and the other features connected with it, i.e. the anal opening into the calyx, the differentiation of the R P R, and the arm-like series of anal plates, has led to much misunderstanding of the true nature of *A. austinii*.

The fine preservation of the first primibrachs all round the cup in Carp. and Eth.'s specimen has apparently kept the oral arch in place although, as already stated, it is considerably sunken at the posterior side of the calyx. For this reason, although the photograph on Fig. 18, Pl. XXIV, does not show the details one could wish in a single print, it makes a beautiful stereoscopic view in which can be seen the tops of the anterior orals nearly in line with the primibrachs and the other orals sloping steeply downwards to the bottom of calyx. In the majority of large specimens such as this one the ring of IBr_1 is not preserved. In some of the medium-sized examples of *A. garpelensis* from Muirkirk where these brachials are in position there is a tendency for the oral arch to sink at the posterior side in a similar way to that seen in Carp. and Eth.'s specimen. It is not quite clear how the arch was attached at the sides in the older specimens. In the smaller specimens, where it is usually present, the oral plates are closely dovetailed in between the radials. Apparently in the older individuals when more arms were developed and the cup further expanded out at the top, the attachment of the arch became less secure ; and if the primibrachs got displaced there was little chance of it being preserved in the fossil state.

It is not my intention to discuss the relationship of all these small forms to the family Allagecrinidae, although it is evident that our conception of the family must now be modified in view of the new facts brought forward in this paper. Professor Wanner and Mr. Weller have gone into the matter in relation to the Timor and American forms but, of course, they were unaware of the presence of an arm-like series of anal plates and anal opening into the calyx in *Allagecrinus austinii*. I would here merely remark that the characters which I have given as distinctive of *A. garpelensis* and *A. biplex* show their close relationship to the type form *A. austinii* as now restricted, and no one, I think, would question the propriety of placing them under that genus. As regards *A. scoticus* and *A. elongatus*, the position is different. Mr. Weller concludes that some of his small species and probably those described by Professor Yakovlev from the Urals and Professor Wanner from Timor, and the " immature " forms of Carp. and Eth. (now *A. scoticus* and *A. elongatus*), cannot be referred to *Allagecrinus* as typified by figs. 2*a*, *b*, and *c* of Carp. and Eth.'s pl. xv, and he places his forms under *Kallimorphocrinus*, a new genus created for them. In separating these American forms from *Allagecrinus*, Mr. Weller lays stress on the character of the radial facets, which differ from *Allagecrinus austinii* and the Timor species described by Professor Wanner in that the opening of the axial canal " is behind



J. Wright, Photo.

Allagecrinus scoticus, sp. nov.: *A. elongatus*, sp. nov.; *A. biplex*, sp. nov.; *A. austinii*, Carp. and Eth. Carlops, Invertiel and Howood.

To face p. 363.]

the cross ridge and in the bottom of the depressed muscle field ", in contrast to *A. austinii* and the Timor species, in which the axial canal is situated at the centre of and on the outside of this ridge. The character of the radial facet in *A. austinii* and *A. garpelensis* may be specially noted from Fig. 14*a*, Pl. XXIV, and Fig. 10, Pl. XXV, or from Carp. and Eth.'s pl. xv, where it is shown on figs. 1*b* and 6*a*. In the very small or young examples of *A. scoticus* or *A. elongatus* and in *A. biplex*, the axial canal and cross-ridge on the radial facets are often difficult or impossible to see, but in well-preserved, usually larger examples, where these features are visible the structure appears to be essentially the same as in *A. austinii*, excepting perhaps that in the young *A. austinii* the outer lip of the R R is more slanted off to the exterior ; whereas in *A. scoticus* and *A. elongatus* the outer lip is narrow and rounded. In distinguishing the Scottish species, therefore, I have had to rely on the other characters, some of which such as the differentiation of the R P R and distinctive anal plate and opening into the calyx are of fundamental importance in the morphology of the crinoid. These characters are fully exemplified in the three species *A. austinii*, *A. garpelensis*, and *A. biplex* ; but they are absent from the other two species, *A. scoticus* and *A. elongatus*, the former of which is in miniature very similar to some of the Timor species (*A. indo-australicus* Wanner, etc.), most of which have an oral arch with hydropore, but no anal plate or anal opening in the calyx. On these grounds there is a strong argument for separating such forms from *Allagecrinus*.[1] It seems possible, therefore, that *A. scoticus* and *A. elongatus* will ultimately be placed under another genus. This aspect of the subject, however, as well as any redefinition of the family Allagecrinidae now required must be left over for the present. Meantime, I have retained both species under *Allagecrinus* as the main purpose of this paper will have been attained if I have succeeded in pointing out the distinctive features of the Scottish specimens hitherto grouped under this genus.

EXPLANATION OF PLATES XXIII–XXV.

Plate XXIII.

Figs. 1 to 12, immature specimens of *A. scoticus*, all × 17 except Fig. 2, which is × 20, from Invertiel. Figs. 13, 14, 15, and 17 : Mature specimens of *A. scoticus*, and Fig. 16, top view of a mature example of the same ; all × 17. Figs. 13, 15, and 17, from Carlops ; Figs. 14 and 16 from Invertiel. Figs. 18 to 25, 28, and 29 : Immature specimens of *A. elongatus*. In Figs. 19 and 20 none of the R facets are developed. In Figs. 21 and 22 the R R are bulging at the top. This is more pronounced in Fig. 18, although it does not appear to have borne arms. In Fig. 23 two only of the R R bore arms. In Fig. 24 the R in middle of photo. bore an arm, but none of the other R facets are developed. In Fig. 28 all the R facets are feebly developed. In Fig. 29 two of the R facets are not developed, one

[1] With regard to Rowley's *A. americanus*, probably Mr. Weller would not have removed this species into another genus had he been aware of the presence of an oral arch, anal plate, etc., as has been shown here to be typical of *A. austinii*.

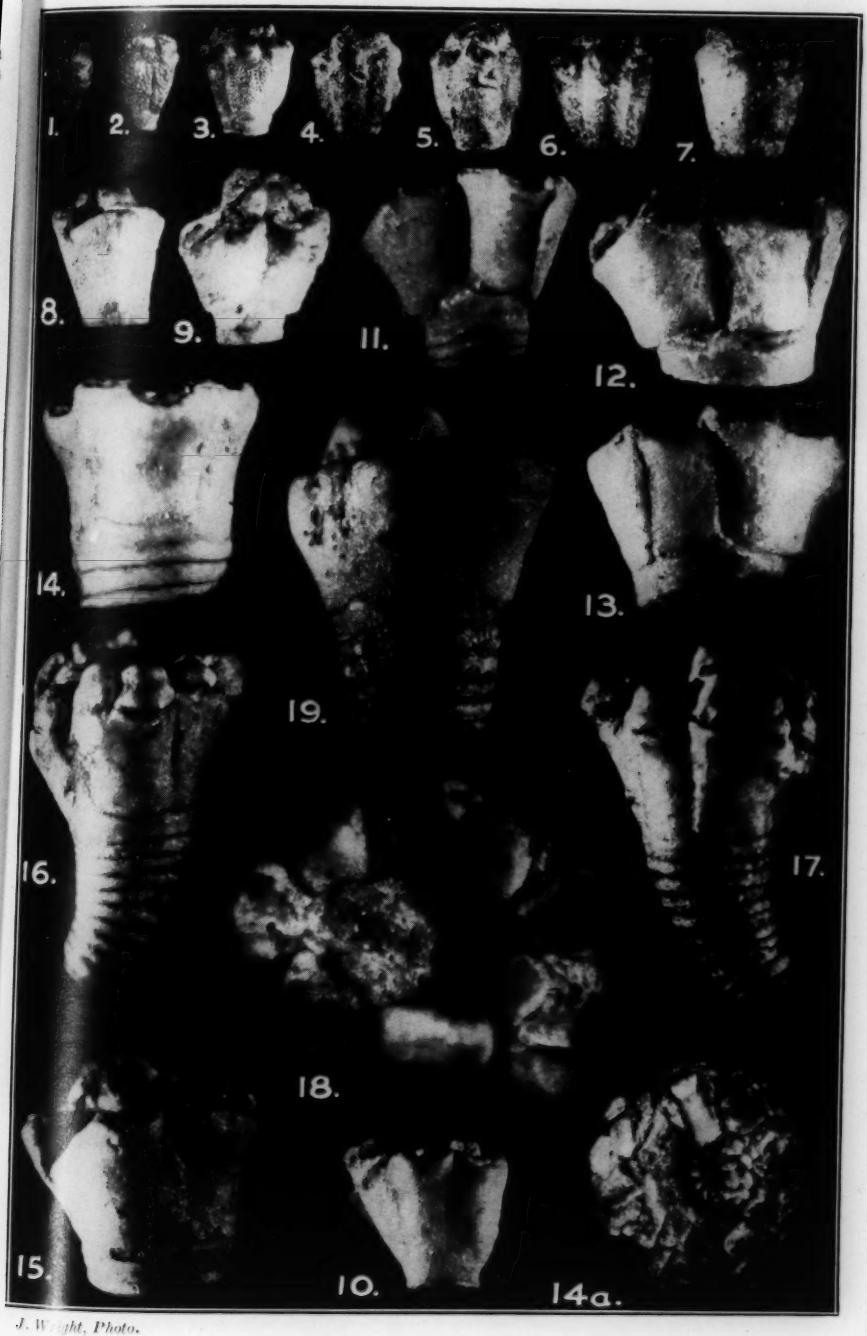
in centre of photo. and one to the rear; actual positions in this specimen are R P R and L A R well developed, R A R feebly so, other two not developed. All × 17. From Howood. Figs. 26, 27, and 30: Medium and mature specimens of *A. elongatus*, × 11, from Howood. Fig 26 has five single R facets; Fig. 27 has one ax. R; and Fig. 30 has three ax. R R. Figs. 31 to 34: Fully matured examples of *A. elongatus*. × 20. All from Invertiel. Figs. 35, 36, and 37: Type specimens of *A. biplex*, posterior, anterior, and side views; × 17. Fig. 38: The same species, × 11, from Invertiel. Figs. 35, 36, and 37 from Carlops. Figs. 39 and 40: Young specimens of *A. austinii*, same as Fig. 2 of Plate XXIV. Figs. 41 to 43: Young specimen of *A. austinii*, same as Fig. 3 of Plate XXIV, showing anal plate on Figs. 42 and 43 and armless R on Fig. 41. Figs. 39 to 43 from Carlops, × 17.

Plate XXIV.

Figs. 1 to 20.—A typical series of specimens of *A. austinii*. Fig. 1: Smallest specimen without arms from Invertiel. Fig. 2: Same specimen as Figs. 39 and 40, Plate XXIII. This example only bore two arms. Fig. 3: Same specimen as Figs. 41, 42, and 43 of Plate XXIII. Both are from Carlops. Fig. 4: Has only three arm-bearing R facets developed, from Invertiel. Fig. 5: Has only four R facets developed, the Ant. R being armless. The armless R is to the right in photograph. Fig. 6: This specimen also had only four arms, the armless Ant. R being to the right in photo. Fig. 7: This specimen had five arms plus anal series. The sloping down of the left shoulder of R P R is well seen in this specimen. Figs. 5, 6, and 7, from Invertiel. Fig. 8: This specimen had seven arms plus anal series, the L P R and R A R being axillary. Photo. from posterior showing differentiation of R P R, from Howood. Fig. 9: Specimen with oral arch in position slightly crushed; R P R to left, R A R to right, five arms plus anal series; from Carlops. Fig. 10: R P R to left, R A R in middle, and Ant. R to right. This specimen had five arms plus anal series. Fig. 11: R P R to left, R A R in middle, Ant. R to right. This specimen had seven arms plus anal series. Ax. R R are L P R and R A R. Fig. 12: R P R to left, R A R in middle, Ant. R to right. Fig. 13: The same specimen from the other side, L P R to right, L A R in middle, Ant. R to left. This specimen had seven arms plus anal series. Ax. R R, L P R, and R A R. Figs. 14 and 14*a*: Originals of Carp. and Eth.'s figs. 1*a* and *b*, pl. xv; eight arms, plus anal series. Fig. 14: R P R to left, R A R in middle, Ant. R to right. Fig. 14*a*: View from the top, R P R at bottom of photograph. Fig. 15: Original of C. and A.'s fig. 6*a*, pl. xv; R P R to left, R A R to right, seven arms plus anal series. Ax. R R, L P R, and R A R. Figs. 16, 17, and 18: Originals of C. and A.'s figs. 2*a*, *b*, and *c*, pl. xv; eight arms plus anal series. Fig. 16: R P R to left, R A R in middle, Ant. R to right. Fig. 17: Ant. R to left and corner of R P R just visible on extreme right, L A R and L P R in middle of photo. Fig. 18: Top view, showing remains of oral arch, also ring of IBr_1 and anal series on right. Fig. 19: Largest specimen from Invertiel; eight arms plus anal series, R P R to left, R A R in middle, Ant. R to right. Unless otherwise stated, all specimens are from Carlops. All figs. × 11, except Fig. 18, which is × 14.

Plate XXV.

Figs. 1 to 13.—A typical series of specimens of *A. garpelensis*. Fig. 1: R P R to left, Ant. R to right; five arms plus anal series. Fig. 2: The same specimen, Ant. R to left, L A R to left centre, L P R to right centre, and R P R just showing on extreme right. Fig. 3: The same specimen from posterior, showing R P R in centre with anal series on left shoulder. Fig. 4: R P R to right, L P R in middle, and L A R to left. Fig. 5: Another specimen from the same position as Fig. 4. Fig. 6: L P R to



J. Wright, Photo.

Allagecrinus austinii, Carp. and Eth. Carlops, Invertiel, and Howood.

[To face p. 364.

J. Wright, Photo.

Allagecrinus garpelensis, sp. nov. Garpel Water, Muirkirk.

To face p. 365.]

right, L A R and Ant. R on left. Fig. 7 : From posterior, R P R in middle of photo. Fig. 8 : R P R to left, Ant. R to right. Fig. 9 : Top view of specimen shown on Fig. 1, showing anal opening into the calyx, plates of the anal series, etc. Fig. 10 : Top view of specimen shown on Fig. 7, showing oral arch, anal opening into calyx, and radial facets, etc. Fig. 11 : From posterior. Fig. 12 : R P R to left, Ant. R to right. Fig. 13 : Ant. R to left, R P R to extreme right. All these specimens had five arms plus anal series, except Fig. 12, which had six arms plus anal series, ax. R here being L P R, and Fig. 13, which had nine arms plus anal series, the ax. R here being L P R, R A R, and the R A R which bore three arms. All specimens from Garpel Water, Muirkirk. All photos × 11, except Figs. 9 and 10, which are × 17.

Postscript.

Since sending this paper to the Editor, I have made another extended examination of washed shale from No. 1 Bed, Invertiel. In these washings I have obtained an additional 819 specimens of *A. scoticus* and 128 of *A. elongatus*, the majority being mature forms, and they confirm in a most satisfactory way all that has already been written.

Besides these, I have also found another five large adult examples of *A. austinii*, details of which are given below. The oral arch is not preserved in these specimens.

1 cup	3	mm.	high	by	3·6	mm.	widest	diameter	—	10	arms	plus anal series.
1 „	2·4	mm.	„	„	3·3	mm.	„	„	—	9	„	„ „ „
1 „	2	mm.	„	„	2·3	mm.	„	„	—	6	„	„ „ „
1 „	1·6	mm.	„	„	2·3	mm.	„	„	—	6	„	„ „ „
1 „	1·7	mm.	„	„	1·9	mm.	„	„	—	5	„	„ „ „

Four intermediate calices of this species, similar to Figs. 3 to 7, Plate XXIV, but much better preserved, were also found. All have the oral arch in position and the anal opening into calyx, differentiation of R P R, etc., are specially well shown. Measurements are as follows :—

1 cup	1·4	mm.	high	by	1·6	mm.	widest	diameter	—	3	arms	plus anal series.
1 „	1·4	mm.	„	„	1·7	mm.	„	„	—	4	„	„ „ „
1 „	1·3	mm.	„	„	1·6	mm.	„	„	—	5	„	„ „ „
1 „	1·3	mm.	„	„	1·5	mm.	„	„	—	4	„	„ „ „

Two of the specimens had only four arms, the top of Ant. R in each case being joined up closely with overlying oral. One specimen had apparently only three arms, since the L P R and Ant. R are poorly developed, the tops of these plates projecting very little beyond the line of the orals, and there is no sign of cross ridge or axial canal. The other cup is normal, all facets being well developed. I find that on two of the specimens, i.e. on the one that had only three arms and one which had four, there is a distinct tubercle or swelling in central area of post. oral and this has led me to further clean the very small specimen shown on Fig. 2, Plate XXIV (Figs. 39 and 40, Pl. XXIII. Here also I notice a similar swelling in central area of post. oral. The specimen shown on Fig. 3, Plate XXIV (Figs. 41, 42,

and 43, Pl. XXIII), exhibits the same feature, but the swelling is much fainter. Whether these swellings indicate the position of a hydropore, I am unable to say. It is possible that such a pore pierced the post. oral in *A. austinii*, but in the small specimens in which this tubercle or swelling is noticeable, I cannot, owing to the coarse or porous nature of the plates, detect any special aperture; and in the older examples in which the oral arch is preserved and the plates are finer in texture, I cannot see any swelling or other feature to suggest its presence. There is, of course, no doubt whatever about the existence of the anal plate and anal opening in these intermediate specimens in which the swelling is seen, and there is also no doubt in my mind that these intermediate specimens are unquestionably immature stages of *A. austinii*. If this tubercle or swelling in some of the small specimens of *A. austinii* does indicate the position of a hydropore, it would be a feature in common with *A. scoticus* and *A. elongatus*, but such specimens are not to be confused with the two latter species which have no anal opening into the calyx and whose general habitus is quite different.

In addition to the above specimens, I have obtained two small crushed cups which undoubtedly belong to different species altogether from those described in these pages. They measure 1·3 mm. high by about the same in widest diameter. The positions of the R R are uncertain. On two of the R R, however, there are four distinct arm-bearing facets, and on the other R R there appear to be two on each; so that we have a form here which had fourteen arms. This species is apparently very rare, but I am continuing the search in the hope of finding more and better preserved specimens.

The Old Basement of Barbados; with some Remarks on Barbadian Geology.

By C. A. Matley, D.Sc., F.G.S.

THE island of Barbados occupies a position of exceptional geographical and geological interest in the West Indian region. Geographically, this island lies outside the festoon chain of the Lesser Antilles and stands isolated as an eastern outpost projecting into the Atlantic. Geologically, it differs in structure and to some extent in the character of its rocks from its neighbours. It is, therefore, important that as much as possible of its geological history should be known. Unfortunately, the Scotland Beds, the oldest formation exposed, are no older than Eocene, and it was with the object of attempting to obtain a clue to the nature of the pre-Tertiary basement that the investigation recorded in these notes was made.

At first it was intended to restrict this paper to the subject of this old basement, but as some important additions to our knowledge

of the island's stratigraphy have resulted from the investigations of Messrs. Beeby Thompson and Partners in their search for oil, I have thought it desirable to give a summary of them, because they have hitherto been accessible only in publications dealing with petroleum[1] and are little known to geologists not interested in that subject. Some additions to the fauna of the Scotland Beds, which I have obtained permission to publish, are also put on record here.

The rock-formations of Barbados have hitherto been classified into three series, separated by unconformities :—Coral-Rock, Oceanic Series, and Scotland Beds. To these Beeby Thompson has recently added a fourth, the Joe's River Clay, lying between the Oceanics and the Scotland Beds. He adds little to our knowledge of the youngest formation, the "Coral-Rock" of Pleistocene and Recent age, which consists of coral limestones and calcareous beach deposits and covers six-sevenths of the island.

The Coral-Rock is underlain unconformably by the "Oceanic Series", the age of which has not yet been satisfactorily determined, but is probably not older than Pliocene. This formation, consisting of globigerinal marls and chalks and siliceous (radiolarian and diatomaceous) earths, with bands of volcanic ash, is regarded as the classic example of elevated "abyssal" deposits, and has been thought to be about 250 to 300 feet thick. It is, therefore, surprising to learn that Beeby Thompson finds the thickness to be "up to 2,000 feet or more", and states :—

> "In the higher parts of the island these beds do not exceed a few hundred feet at most, but to the south they appear to thicken enormously, and one well carried to 3,200 feet failed to penetrate them. This must mean that during their deposition Barbados was being submerged, so that much thicker deposits accumulated on the flanks." (Op. cit., 396.)

Deposits formed at oceanic depths are considered to have accumulated extremely slowly and uniformly. Even when adequate allowance is made for the air-borne volcanic detritus which the Barbados beds contain, their thickness is still so great that a re-examination of the claim that they were deposited at depths (varying with the nature of the material) up to at least 2,000 fathoms[2] seems desirable. The opinion that these strata were raised from oceanic depths seemed at the time to be confirmed by the discovery in them (in a radiolarian marl) of an echinoderm *Cystechinus crassus* Gregory,[3] because living members of this genus have never been found at depths less than 1,000 fathoms, but the value of this fossil as a criterion of oceanic depths is now much diminished because the same, or a closely-related, species has been

[1] See A. Beeby Thompson, "Oil-Field Exploration and Development": vol. i, *Oil-Field Principles* (London, 1925), 394 et seq.
[2] Harrison and Jukes-Browne, *The Geology of Barbados*, 1890, 37.
[3] J. W. Gregory, *Quart. Jour. Geol. Soc.*, xlv, 1889, 640–50.

recognized in beds not of deep-sea origin near Suva, in the Fiji Islands.[1]

A most interesting formation, up to a few hundred feet thick, has been found by Beeby Thompson to lie unconformably between the Oceanic Series and the Scotland Beds. He calls it the "Joe's River Clay" and states that:—

> "It consists of a dead-black oil-soaked clay containing numerous angular fragments of sandstone of sizes up to many feet across. . . . All the sandstones are saturated with heavy oil and the amount of inspissated petroleum represented in the Joe's River Clays must be enormous. . . . From its nature and mode of occurrence there can be little doubt that it represents the debris from vast mud volcanoes, probably submarine, and probably due to the high gas pressure in the St. Andrew's beds." (Op. cit., 396.)

We now come to the Scotland Series, the oldest formation exposed. It is a thick group of shallow-water sediments, mostly unfossiliferous, consisting of sandstones, grits, clays, etc., which were strongly folded and even overturned and overthrust before the Joe's River Clay and the Oceanic Series were laid down on their denuded edges. An example of the folding is shown in Fig. 1. Since the early accounts

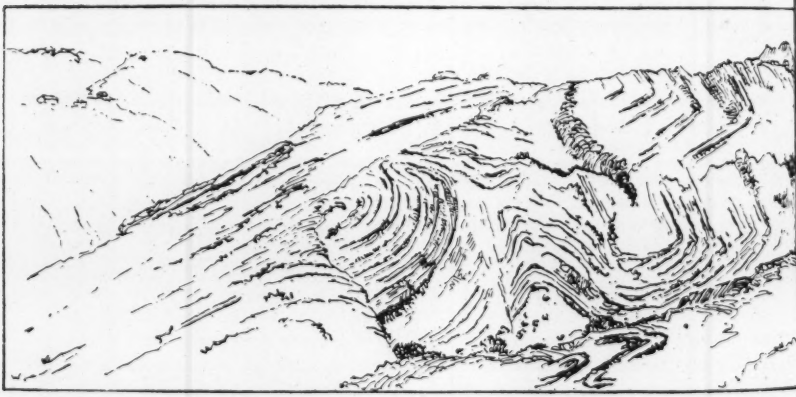


FIG. 1.—Sketch of the folding of the Scotland Beds near Chalky Mount, looking south-west. (Drawn by Mr. A. F. Williams from a photograph by Mr. A. Beeby Thompson.)

of Harrison and Jukes-Browne were written this series has become the subject of detailed investigation for oil by E. H. Cunningham Craig,[2] and later by Beeby Thompson and Partners. Beeby Thompson divides the formation into two groups. Of the lower group (St. Andrew's Beds) he says:—"The base of this series is unknown, but from drilling records it is believed to be several

[1] C. A. Matley and A. Morley Davies, "Some Observations on the Geology of Viti Levu": GEOL. MAG., LXIV, 1927, 69.

[2] *Report on the Oil Fields of Barbados*, 1913.

thousand feet thick, and with a thick sandy shale series below the upper sands." (Op. cit., 395.) The upper group, which he terms "Chalky Mount and Mount All Beds", is much thinner. It is essentially arenaceous, with, however, some interbedded clays and with a fairly constant conglomerate at the base. At Chalky Mount itself is a thickness of sandy strata above the conglomerate, but this is interpreted as a duplication of 250 feet of rock by isoclinal folding. (See Fig. 2, kindly supplied to me by Messrs. Thompson and Romanes.) The Mount All Beds "may eventually be separable into an upper division". (Op. cit., 395.)

The conglomerate bed at the base of the Chalky Mount Group is of special importance as almost all the identifiable fossils obtained from the Scotland Series have come from this horizon. A collection made from it by Mr. James Romanes in 1921–2 was sent to the British Museum (Natural History) and reported on by the late Mr. R. Bullen Newton in July, 1922; the report was not published, but the rough manuscript is preserved, with the specimens, and was kindly shown to me by Mr. L. R. Cox. A further and larger collection was made later by Dr. C. T. Trechmann, who described the rich molluscan fauna in this Magazine in December, 1925 (481–504). He records the presence of more than 50 genera, including 6 new species and 2 new varieties. Mr. T. H. Withers described the decapod crustacea (three species of *Callianassa*) in this Magazine in 1926 (104–8). The foraminifera and corals have since been examined for Dr. Trechmann by Professor A. Morley Davies and Dr. T. Wayland Vaughan respectively, and their identifications are as follows:—

Foraminifera.
Nummulites variolarius (Lamk.).
Discocyclina cf. *varians* (Kaufmann).
Corals.
Asterosmilia cf. *hilli* Vaughan.
Stephanocoenia (?) sp.
Madracis (?) sp.
Pavona sp.

Trechmann also described the mollusca preserved in some isolated masses of very hard sandstone which he thinks came from a bed "possibly 150 feet or more below the bed of conglomerate", and, therefore, from the upper part of the St. Andrew's Group. These mollusca are of fresh-water aspect (*Unio*, *Cyrena*, *Ampullaria*, etc.) and occur in a fresh and unbroken condition, whereas the fossils in the conglomerate bed are mostly broken and rolled (including some rolled fresh-water forms) or are contained in pieces of sandstone derived from an older bed. This fact has, of course, to be considered when judging the age of the conglomerate.

From his study of the mollusca of the Chalky Mount conglomerate, Trechmann's opinion is that "the horizon of the fauna seems to

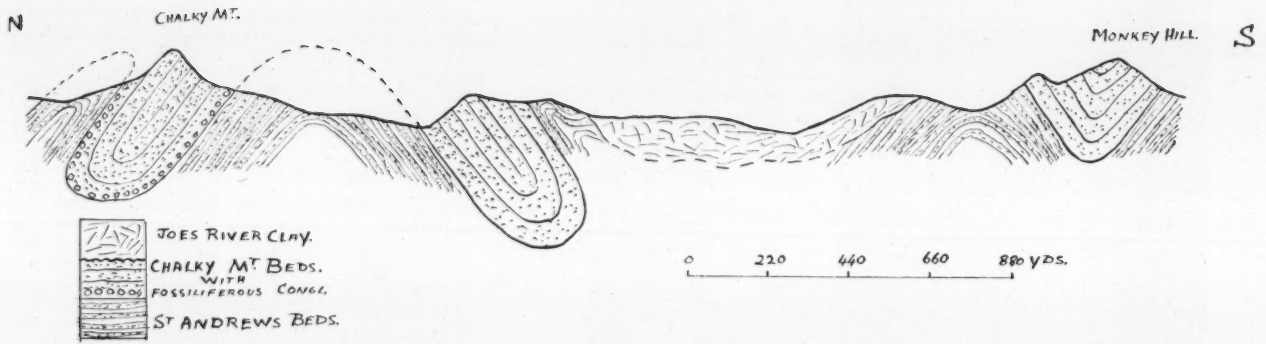


Fig. 2.—Section across the Scotland Series at Chalky Mount, by Mr. James Romanes.

be high in the Middle Eocene, or rather low in the Upper Eocene (Lutetian-Auversian-Bartonian). Professor Morley Davies tells me that the little nummulite *N. variolarius* is definitely Upper Eocene (Auversian). R. B. Newton, in his unpublished report, discussed the age of the fauna and concluded that "the general facies of the whole fauna may be summed up in the compound term Bartonian-Priabonian".

Although Newton found in the Romanes collection fewer forms than Trechmann collected he recognized two which deserve mention here. A Siluroid fish, *Socnopaea* cf. *grandis* Stromer, is represented by two fragments, a part of a cranial bone showing external sculpture markings, and a well preserved, although incomplete, pectoral spine (90 mm. long) with good articular end. The type of this species comes from the Upper Mokattam (Bartonian) of Egypt. The other form is the foraminiferal genus *Pellatispira* of Boussac (*Bull. Soc. Geol. France*, 1906, **4**, vol. 6, 91, pl. 2, figs. 10–13), "which has the shell texture of *Calcarina* besides sharing certain resemblances with *Assilina*, this being an interesting occurrence on account of its restricted range in time, being found only in the Bartonian-Priabonian deposits of Italy, Hungary, New Caledonia, Borneo, and in some islands of the Japanese seas" (R. B. Newton's manuscript). This form occurs associated with 'Orthophragmina' and small nummulites in a petroliferous sandstone boulder in the Joe's River Clay derived from the Scotland Series. It may also be mentioned that Newton determined the coral genera *Paracyathus* and *Astrocoenia* in the Romanes collection.

We come now to the question of the old basement of Barbados. During a short visit to the island in November, 1929, it occurred to me that an examination of the material of which the Scotland Beds are composed might give some indication of the nature of the old land from which these sediments came. Trechmann's account of 1925 (I was not then aware of Beeby Thompson's) indicated that the coarsest sediment was the conglomerate at Chalky Mount. I visited the spot and brought away samples. The rock there, which is rather friable at the outcrop and readily disintegrates, is more or less cemented by a limonitic clay, and contains an abundant sandy matrix, made of quartz grains, with small pebbles of quartz, mostly $\frac{1}{4}$ inch or under in diameter and rarely exceeding $\frac{1}{2}$ inch in length. Some of the pebbles are well abraded, but others are slightly worn, broken crystals, which, together with the variations in grain-size, indicate deposition under shallow-water conditions fairly close to the source of the material. Some of the quartz is blue and opalescent, some milky, most of it nearly colourless. Apart from claystone nodules, quartz is the only kind of inclusion seen with the naked eye. This is confirmed by Trechmann, who, writing in 1925, said:—"Although a careful search was made no trace of igneous or metamorphic derived rocks was seen in any of the Scotland conglomerates" (op. cit., 485), but he permits me

to say that he has since found a small piece of crystalline limestone (coarse-grained marble), like that of the Northern Range of Trinidad or Isle of Pines, in the fossil bed at "Sunbeam" below Turner's Hall Wood.

Some of the matrix was brought to England for further examination and, by the kindness of Professor P. G. H. Boswell, its heavy residues have been separated at the Royal School of Mines by Professor Illing who prepared microscope slides which were handed to Mr. Smith Bracewell, B.Sc., F.G.S., for study. Mr. Bracewell reports that the matrix of the conglomerate consists almost entirely of quartz, no felspar can be found and the only mica seen occurs as very small flakes attached to the quartz pebbles. Some of the quartz pebbles were examined microscopically after crushing, the fragments giving positive interference figures and parts of some of the grains being microcrystalline aggregates. The broken quartz-crystals are such as might have been derived from a granite, but the absence of felspar militates against this view, and the alternative derivation is a quartz-schist or quartzite and the quartz-veins which intersect such rocks.

The heavy residues obtained by bromoform separation are very small in quantity, and the size of the grains ranges from $\frac{1}{100}$ inch in diameter downwards. The minerals present are magnetite, leucoxene (?), limonite, tourmaline, zircon, kyanite, rutile, garnet, chlorite, amphibole (?), epidote, andalusite, and green spinel. The iron ores, especially magnetite, are by far the most abundant, tourmaline comes next, though very subordinate to the above; zircon, rutile, and kyanite are well represented. A few grains of pinkish isotropic garnet of very irregular shape were found. Only one grain of andalusite and one of spinel (pleonaste) were observed.

Samples from other horizons in the Scotland Series have since been selected from the Romanes collection in the Natural History Museum, and Mr. Bracewell has examined the residues therefrom by panning. They have on the whole the same character as from the conglomerate bed. For example, from the Mount All Group of Mount All were obtained magnetite (abundant), zircons (common), tourmaline, kyanite, rutile, staurolite (?), a greenish-yellow mineral (? epidote), and a bluish-green pleochroic mineral.

The assemblage of minerals, light and heavy, provides evidence of derivation from metamorphic rocks, the presence of kyanite, andalusite, and garnet pointing particularly to such an origin. This old land must have lain close to the present island and been of extensive area as it provided material for shallow-water deposits several thousand feet thick, which must have been laid down in a subsiding area, probably part of a geosyncline that was subsequently piled up by mountain-folding.

The rocks from which the Scotland Beds were derived were certainly of pre-Tertiary age, and the nearest areas to Barbados where pre-Tertiary rocks are exposed at the present day are the

island of Tobago and the Northern Range of Trinidad; both are extensions of the great Cordillera of Venezuela. Both these areas consist mainly of metamorphic rocks, chiefly of sedimentary origin, although in Tobago especially, altered igneous rocks (classified broadly by Cunningham Craig as "epidiorites") also occur. They contain considerable thicknesses of quartz-schist, quartzite, and quartzose grits, which, if denuded, would provide suitable material for forming pebbly sandstones like those of Chalky Mount; there are crystalline limestones from which pebbles of white marble like the one found by Trechmann could be formed, and there are plenty of soft argillaceous and ferruginous schists from which the clays and ironstones could be produced. It is, therefore, suggested that the old basement of Barbados and of the surrounding region now deeply buried below the sea is formed of metamorphic rocks of the same general character as those found in the Cordillera of Venezuela and its easterly extensions in Tobago and Trinidad.

This suggestion seems at first sight to support the view Suess held of the tectonic significance of Barbados. He placed Barbados on the great curved orogenic fold (called by him the middle or principal zone of the West Indian islands) that, in his opinion, runs through the Greater Antilles and then turning southward through Barbados swings westward along the coastal range of Trinidad and Venezuela, Barbados being one of "the visible remnants of a once continuous mountain range".[1] If this view is sound then the strike of the Barbadian rocks should be north–south, as the trend of Suess's fold in that area runs in a meridional direction.[2] At the suggestion of the late Professor J. W. Gregory, who seemed doubtful about the course of the fold, I made observations and inquiries in Barbados as to the directions of folding in the rocks of the island and found that, although they varied in detail, they approached a north-east to south-west direction, and that the north–south strike expected on Suess's hypothesis is conspicuously absent. The tectonics of Barbados are discussed by Thompson, who shows that the intense plication of the Scotland Beds is dominantly along north-east–south-west axes and the gentler folding that affected the Oceanic Series runs more nearly east and west. It is apparent, therefore, that the folded rocks of Barbados are truncated remnants of beds that projected into the Atlantic and did not turn northwards in this area to join the folding of the Greater Antilles.

In conclusion I wish to express my indebtedness to those whose names are mentioned in this paper and without whose help it could not have been written.

[1] E. Suess, *The Face of the Earth*, English edition, i, 1904, 549.
[2] See F. R. C. Reed, *The Geology of the British Empire*, 1921, Map, fig. 12.

The Glacial Sequence in the North of England.

By F. M. Trotter, D.Sc., and S. E. Hollingworth, M.A., D.Sc.

In recent years great progress has been made in the correlations of the Glacial deposits with the culture stages of the Palaeolithic period. In particular the recent papers of Professor P. G. H. Boswell (1) [1] and Dr. K. S. Sandford (15), whilst adding considerably to our knowledge, have at the same time brought out the inherent difficulties that arise in any attempt to correlate the culture stages with the sequence of glaciations.

In the outer belt of the area affected by the Pleistocene ice sheets there is an interdigitation of Glacial deposits with deposits containing implements that were contemporaneous with the occupation of the area by Palaeolithic man. The ice of this zone, or belt, of interdigitation was, to a large extent, the feather edge of the thick sheets that occupied the regions to the north and deposited great sheets of boulder-clay containing distinctive boulder suites and separated from each other by water-laid spreads of sand and gravel. In the southern area the glacial deposits are often comparatively thin and may be locally missing. They are patchy in distribution and are so much modified, compared with their northern equivalents, by the introduction of local material and by the incorporation of boulders from earlier drifts that their correlation on lithological and stratigraphical grounds is a matter of some complexity. Moreover, it would appear that the best known of the true boulder-clays and other glacial deposits in the south represent the earlier glaciations of the North of England, whereas the later glaciations of the northern area are but feebly represented by true boulder-clays in the south.

Professor Boswell is undertaking a comprehensive survey of the relations of the culture stages and the various glacial episodes over the whole of England, and in discussing this problem with us has suggested that a short account of the glacial sequence of the North of England would help to clear up the difficulties in correlating the drifts of the Irish Sea and North Sea drainage basins.

A large band of enthusiastic glaciologists, inspired by Kendall's work on the Cleveland Hills (10), have tackled the glacial problems of the North of England, each working out in detail the glacial history of a particular area, but the realization of the complexity of the superficial deposits has effectively discouraged correlation with outside areas. Woolacott's paper on Northumberland and Durham (24) is, however, a notable exception, for by analysing and comparing the results of his own labours with those of Trechmann (21), Merrick (13), Herdman (6), Smythe (19), and Dwerryhouse (5) he was able to portray the glacial history of that area.

[1] Figures in parentheses relate to References at end of article.

His survey may now be carried further afield with confidence, for although the detailed glacial history of large tracts has yet to be worked out, nevertheless contact has been established along a wide front. In particular, the links in the chain of evidence are complete from east to west, from the Cleveland Hills via Stainmore to the Lake District, and, farther north, from the Northumberland coast via the Tyne Gap to the Lake District. The Tyne Gap area also links up with the Solway and the Southern Uplands.

Woolacott recognized four boulder-clays, separated in places by "interval-deposits". It will be convenient to group each boulder-clay and the gravels which overlie it as representing one Glacial Episode, thus obviating the necessity of entering into the vexed question as to whether the interval-deposits represent true Inter-Glacial Periods.

Woolacott's sequence interpreted in terms of Glacial Episodes is as follows [1]:—

Episode 4. Retreat phenomena—outwash gravels and overflow channels.
Northern Clay (Cheviot and Scottish) on coastal plain, Western Clay inland.
" 3. Interval-deposits: gravels, etc.
Western (Lake District, Pennine, and Southern Uplands) Clay.
" 2. Interval-deposits.
Northern (Scottish) Clay on coastal plain.
" 1. Interval-deposits.
Scandinavian Clay.

The correlation of this sequence with the fourfold division of Yorkshire—Scandinavian Clay, Lower Purple Clay, Upper Purple Clay, and Hessle Clay [2]—seems definite, for not only do the Glacial Episodes of the two areas agree in number but they also correspond in boulder content. Moreover, Professor Kendall traces the uppermost division (Hessle Clay) along the whole of the Yorkshire coast around the Cleveland Hills to County Durham (11). Again, the retreat phenomena of Episode 4 have been traced back from the Cleveland Hills by a series of outwash gravels and overflows northwards through County Durham to the Tyne by Woolacott, Trechmann, and Herdman.[3]

[1] It may be remarked that whilst Woolacott in "print" adopted the attitude that the interval-deposits did not necessarily indicate Interglacial Periods because of the monoglacial theory then prevailing, nevertheless he indicated to one of us that he considered the four boulder-clays to represent distinct glaciations—an interpretation with which we are in complete agreement. Trechmann considers (21) that the interval deposits between Episodes 3 and 4 and Episodes 1 and 2 represent Interglacial Periods.

[2] The correlation of this sequence with that put forward for East Anglia—Norwich Brickearth, Cromer Till, and Chalky-Neocomian Boulder Clay, Upper Chalky Boulder Clay (Upper Chalky Drift), and Hunstanton Clay—forms the subject of a recent letter by Professor Boswell to the GEOLOGICAL MAGAZINE (March, 1932, p. 143).

[3] A point fully appreciated by Kendall and Wroot (13, p. 471), who describe the shrinkage of the ice of the Hessle Clay episode from Cromer to the Lammermuirs.

The retreat phase of this 4th Episode may also be followed westwards to the Pennine Dales and to the Lake District [see Dwerry-house (5), Raistrick (14), and the writers (7 and 22)], where it is represented by the outwash gravels of the Main Glaciation.

South of the River Tyne the retreat has been traced back to the Alston Block and the Lake District by Herdman, Dwerryhouse, and the writers. In Northumberland, Smythe (19) has worked out the progressive split from south to north of the Cheviot Ice from the Western (Lake District and Southern Upland) Ice, and we have carried the story westward from Northumberland to the Lake District and the Scottish side of the Solway. It is beyond dispute, therefore, that the Main Glaciation of the Lake District and Northern Pennines falls into Episode 4.

It is highly probable also that the Early Scottish Glaciation of Cumberland equates with the Western Ice of the north-east coast and is, therefore, referable to Episode 3. In both areas we have evidence of a powerful glaciation from the west. In Edenside, in spite of the close proximity of the Lake District, the glacier from the Southern Uplands advanced up Edenside and, with Lake District Ice, swept across Stainmore to reach the coast north of the Cleveland Hills. The northern branch of this glacier, which advanced across Northumberland, also reached the coast (Smythe, 19). Indeed, if we agree with Charlesworth (4) that the British and Scandinavian (or North Sea) Ice were not confluent during the period represented by the Hessle Clay, then the fact that the Western Ice sheet reached the north-east coast during Episode 3, presumably deflecting the Cheviot Ice into the North Sea, indicates a glaciation of greater magnitude than that of Episode 4.

Thus far, then, this correlation appears to be beyond reasonable doubt and, as it forms the basis of a survey of the glacial sequence farther afield, it may be briefly restated: Episode 4 is represented by the Hessle Clay in Yorkshire, by the Cheviot and Western Clays in Northumberland and Durham, and by the Main Glaciation Clays of the Lake District and adjoining areas. Episode 3 is represented by interval-deposits in all three areas, and by the ground moraine of this episode is respectively known as the Upper Purple, the Western, and the Early Scottish boulder-clays. The earlier of these two glaciations (i.e. Episode 3) appears to have been the more extensive.

These episodes have also been recognized by Dr. Bernard Smith in the Isle of Man (18).

At and adjacent to the centres of ice accumulation such as the Lake District it is not surprising that deposits indicating glaciations earlier than Episode 3 are rarely seen. Nevertheless there appears to be evidence in Cumberland of at least one glacial episode that is earlier than the Early Scottish Glaciation.

A correlation of the Glacial sequence of the various areas is appended in the following table :—

TABLE SHOWING THE CORRELATION OF THE GLACIAL DEPOSITS IN THE NORTH OF ENGLAND.

	WEST.		EAST.	
	Southern Part of the Irish Sea Basin.	Lake District and the Solway Firth.	Northumberland and Durham.	Yorkshire.
FIFTH GLACIAL EPISODE.		Retreat Phenomena : lakes, channels, sands and gravels, and laminated clays. Scottish Readvance Boulder Clay.	Not represented.	Not represented.
FOURTH GLACIAL EPISODE.		Retreat Phenomena : lakes, channels, sands and gravels, and laminated clays, (= Middle Sands of Carlisle).	Retreat Phenomena : lakes, channels, sands, and gravels.	Retreat, Phenomena : lakes, channels, sands and gravels.
	? Upper Boulder-Clay of Liverpool district.	Boulder-clay of Ice of Lake District–Edenside Maximum and N. Pennines.	Prismatic Boulder-Clay, Cheviot and Scottish Ice with Western Ice in the west.	Hessle Clay and its inland equivalents.
THIRD GLACIAL EPISODE.	Middle Sands and Gravels.	Gravels and laminated clays.	Gravels and laminated Clays.	Gravels, etc.
	? Lower Boulder-Clay of Liverpool district.	Boulder-clay of "Early Scottish Glaciation" (including Lake District Ice).	Boulder-clay of Western Ice.	Upper Purple Clay.
SECOND GLACIAL EPISODE.			Gravels.	Gravels.
		? Weathered Boulder-clay of Upper Caldew Valley.	Boulder-clay of Scottish and Western Ice.	Lower Purple Clay.
FIRST GLACIAL EPISODE.	Represented farther south.		Loess.	
			Scandinavian Clay.	Basement (Scandinavian) Clay.

A boulder-clay in the River Caldew has been found recently by one of us which differs from the deposits referred to above in yielding a suite of Lake District erratics that are in an advanced stage of decomposition. All possess deeply weathered skins and many are rotten throughout. This deposit is probably older than the Early Scottish Glaciation (Episode 3).

Across the Carlisle Plain the recessional deposits of the Main Glaciation (Episode 4) are overlain by an Upper Boulder-Clay (Scottish Readvance Boulder-Clay) yielding a Southern Upland suite of erratics (22).

A few details of this 5th Glacial Episode are necessary in order to facilitate the comparison between the Glacial sequence of Cumberland with that of Lancashire which is attempted later. The ice of this 5th Episode compares unfavourably with its predecessors in erosive power, extent, and probably in its duration. In the Carlisle Plain it failed to override ground above the 450 feet contour and, well within the limits of its maximum extent, glacial forms—deltas, oses, drumlins, etc.—of the previous glaciation are but slightly modified, being merely plastered with a thin skin of boulder-clay. During this episode there is no definite evidence of glaciers moving outward from the Lake District (7, pp. 322–3) or the Northern Pennines, and its boulder-clay yields erratics that are dominantly a Southern Upland suite even in those areas where it overlies Lake District deposits of the Main Glaciation.

It must be emphasized that this glaciation emanated afresh from the Southern Uplands and was not a readvance of the Main Glaciation Ice from the Irish Sea Basin. The recessional deposits can be traced by the Smithfield–Gretna and Broomhills–Cummertrees ose-trains from its maximum extension on the Carlisle Plain west-north-westwards into Scotland (22), where they link up with the moraines described by Charlesworth (2), who in turn traces the retreat of the valley glaciers into the heart of the Southern Uplands. If the dome of ice in the northern part of the Irish Sea Basin, postulated by Lamplugh (14), ever existed it had completely disappeared before the Scottish Readvance Glaciation. This Readvance Ice appears to have impinged on the coast at St. Bees, south of Whitehaven, where its ground moraine overlies an interval-deposit of peat, silts and loams (17), and it may have extended as far south as the Whicham Valley (16). It may be correlated with a similar Scottish Readvance on to the coast of Northern Ireland. Professor J. K. Charlesworth considers that the Bride Moraines of the Isle of Man mark its maximum extension (3), but Dr. Smith regards these as evidence of a prolonged halt stage in the retreat of the Readvance Ice (18).

The examples given above will suffice to show the limited extent of this glaciation. Confirmatory evidence, moreover, is found in the glacier-dammed lakes that were held up by the Scottish Readvance Ice in the Solway area, both at or near its maximum

extension and during its retreat. The altitudes of these lakes decrease fairly rapidly to the south-west, and indicate a pronounced fall in the surface level of the ice in that direction.

Although it is difficult to define precisely the southern limit of this glacier across the Irish Sea, the evidence on both sides of it would appear to show that this ice did not extend southwards beyond the latitude of Furness.

This 5th Glacial Episode is not represented by glacial deposits on the East Coast of England.

Turning to the south of the Lake District, we find gaps in the chain of evidence. Tiddeman (20) and Jowitt (8 and 9) recognized one boulder-clay only in east Lancashire, as did Goodchild farther north. It is, however, possible to suggest a correlation of the glacial sequence found in the coastal regions of Lancashire, Cheshire, and Flintshire. Here two boulder-clays, separated by gravels and yielding a mixed Lake District-Scottish suite of erratics, are present (23).

From our knowledge of the character and extent of the Scottish Readvance Glaciation in the Solway area it is, in our opinion, improbable that the upper of these two clays represents Episode 5, and it would appear that there is additional evidence against such a correlation in the boulder suite which, although including some Scottish rocks, is dominantly of Lake District origin, thus resembling the lower clay. A correlation of the two clays with Episodes 3 and 4 seems probable. The boulder-clay which sealed the Welsh caves is accepted as corresponding to the Hessle Clay and it would thus appear to be the same clay as the Upper Boulder-Clay of Liverpool.

Farther south we enter into the domain of Midland and Southern glaciologists, but it may be remarked that there is stratigraphical and archaeological evidence for two cold periods prior to Episode 3.

To sum up: A stratigraphical sequence of four distinct boulder-clays separated in places by interval-deposits is present in the North-East of England, and additionally a 5th boulder-clay is recognized in the Solway region. This last would correlate with the Buhlstadium of the Continent if the Continental equivalents of the other four are Günz to Würm.

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REVIEWS.

THE UNSTABLE EARTH: SOME RECENT VIEWS IN GEOMORPHOLOGY. By J. A. STEERS, M.A. With 66 maps and diagrams. Methuen and Co.

THIS book is, on the whole, a useful compilation, but it is not of equal merit throughout. It is divided into two main sections: (*a*) dealing with the major structural features of the earth's surface; (*b*) problems connected with the fluctuations of sea level in recent times.

The second section is by far the best; perhaps this is inevitable, for the author is primarily a geographer, and he frankly acknowledges in his introduction that the subject is not treated from the standpoint of the stratigraphical geologist. Structure and stratigraphy are, however, such Siamese twins that separation cannot be effected without the danger of fatal consequences, as has happened here. If the author had applied the careful analytical and *stratigraphical* methods he has followed with such success in the second part of his book, he would, in all probability, have avoided the mistakes that spoil the first part. These are to be found chiefly in the part dealing with mountain structures.

The author does not seem to be aware that a detailed comparison of the Baltic and Canadian Shields upon a diastrophic basis has already been made with some success; nor that the marine Devonian beds of South Africa (Bokkeveld Beds) are not confined to the margin of that continent but are involved in the Cape Fold Ranges, some considerable distance inland.

If he had realized how largely the metamorphic rocks of the Highlands have contributed to the Lower Palaeozoic sediments of South Scotland, he would surely have understood that the Highland Mountains must belong to an Orogeny long previous to the Caledonian, and that therefore the orogenic features of the south-west Highlands have little or nothing to do with those of the classic north-west, either in point of structure or time. Steers is obviously an ardent Koberite, and tends to fall into just the same errors as Kober himself. If he wants a "pair" for his Caledonian structures of the north-west Highlands, he should look not in the south-west Highlands, but a good deal further south in the region of Anglesey and North Wales.

There has been considerable confusion in the use (and misuse) of the terms Hercynian, Variscan, and Armorican, but it certainly does not help matters to have them used as synonymous terms. A mountain system may be composed of many mountain arcs, a mountain arc of many ranges or chains. The Hercynian Mountain

System contains two important arcs in Europe as Suess so clearly showed : (*a*) the Armorican in the west and (*b*) the Variscan, "the shattered mountain chain of Central Europe." There are others also, but there is little justification for the use of the term Variscan in the place of Hercynian. The greater may contain the less, but not vice versa. Variscan Urals give a nasty jar !

The author too, is guilty of some inconsistencies in this section; he rightly emphasizes a fact, which cannot be urged too strongly upon geologists and geographers alike, that mountain systems rise to their culmination by a long sequence of events covering considerable periods of geological time, and the type of terminology applied to the Alpine fold system might with great advantage be used for every other great fold system of earlier date ; he should not then refer to the time of " Permo-Carboniferous mountain building ", for a system of folding that exercised a profound control upon the sedimentation of the Lower Carboniferous.

Posthumous folding seems to merit more adequate treatment than in an appendix, for it is often the only evidence now available of old fold lines belonging to an ancient mountain system which has exercised a most important control upon the development of the subsequent structure of a region. Witness the Charnian Fold system of the British Isles. There is a good chapter on recent theories, and the author then reaches the second section of his book in which he is clearly more at home ; much useful information has been collected and put together here, with some good criticisms and indications as to difficulties and anomalies in interpretation in dealing with the questions of raised beaches and river terraces. In the part dealing with sedimentation during transgression and regression, it might have been advisable to have drawn attention to the principle of diachronism, which is far too frequently overlooked. Not the least interesting part of this section of the book is the summary of the present state of our knowledge regarding the origin of the Great Barrier Reef, a subject upon which the author writes from first-hand knowledge.

This second part of the book is so good that it justifies the whole ; it is to be hoped, however, that a second edition may see some modification of the earlier part so as to bring the whole up to the same level.

G. L. E.

THE GRAND COULEE. By J. HARLEN BRETZ. Special Publication No. 15. American Geographical Society.

THE best parts about this book are its beautiful illustrations and stereoscopic photographs. The evidence upon which the interpretation of the structure is based seems so slender that it carries little conviction with it.

G. L. E.

CANYON COUNTRY. By JULIUS F. STONE. With more than 300 illustrations and a map. London and New York: Putnam's Sons. Price $5·00.

THE justification for the publication of this book lies in the wealth of beautiful illustrations with their explanatory text; for the rest it is an account of a boat trip through the canyons of the Green and Colorado rivers, and there is little information that can be classed as scientific.

G. L. E.

CHEMICAL ANALYSES OF IGNEOUS ROCKS, METAMORPHIC ROCKS AND MINERALS. pp. v + 166. *Mem. Geol. Survey*, 1931. Price, 3*s.* 6*d.*

SOME years ago the Director of H.M. Geological Survey consulted a number of petrologists as to whether such a work as the present would be useful: the replies were encouraging and the work of compilation was duly carried out by Miss E. M. Guppy, very brief petrographical descriptions by Dr. Thomas being appended to each analysis. A work of this kind is in no need of review, since all the analyses have been published before. We can only say that its appearance is most welcome and it cannot fail to be highly appreciated, as it contains, in a handy form, all analyses of igneous and metamorphic rocks and minerals recorded by the Geological Survey in its very numerous publications. A final section by Messrs. F. R. Ennos and R. Sutcliffe gives an account of analytical methods. It is to be hoped that there will be a similar volume dealing with the sediments.

CORRESPONDENCE.

SCREE SLOPES.

SIR,—I have often heard it said that a scree rests at the angle of repose; that is, the steepest angle such that friction is capable of maintaining the material at rest. This is clearly untrue. If it were so the scree would be indefinitely easily disturbed; a fly alighting on one of the stones would set the whole slope moving, and motion could not stop until there had been a uniform reduction of level everywhere. Actually all screes have a definite margin of stability, though this is often small.

A different criterion emerges if we consider the actual mode of formation of a scree. It is a dynamical process, not a statical one.

A stone falling near the top of the slope rebounds and travels downwards. At the first impact it acquires a rotation, and its velocity is reduced. Between any two successive impacts there is a gain of energy equal to the work done by gravity. But at every impact there is a loss due to friction and imperfect restitution; this depends on the relative orientation of the surfaces that actually come in contact. If the slope is so steep that the gain of energy between two impacts is greater than the loss at an average impact, the stone will, on the whole, gain energy as it proceeds, and will travel to the bottom, thereby reducing the slope at the foot. If the loss on impact is the greater, a certain number of impacts will suffice to bring the stone to rest near the top of the slope, thereby increasing the slope at the top. There will be a critical slope such that the rolling stone will, on the whole, neither gain nor lose energy. If the slope is less, new material will build up the top; if it is greater, new material will build up the bottom. Thus this critical slope will be approached, and when attained will be stable.

The stones already in position will be oriented in a variety of ways, and there is accordingly a considerable range of variation in the circumstances of the individual impacts. But since we are considering the variation of the energy of the stone over several impacts, the losses of energy at many different orientations are averaged. The mean loss of energy per impact over several impacts will vary from stone to stone much less than the losses at single impacts, by the usual statistical principles. This provides an explanation of the observed uniformity of scree slopes.

HAROLD JEFFREYS.

Notice to Contributors.

It would often save time and trouble to the Editor if contributors would be kind enough to write on the back of the last page of their MSS. the address to which proofs should be sent. The reason for this request is that proofs are often sent out by the Editor when away from Cambridge and he does not always remember to take all the necessary records with him. If contributors expect to go abroad at any definite date this should also be noted.

Professor A. Hutchinson.

After the painting by Sir William Rothenstein.

Presentation to Prof. A. Hutchinson, F.R.S., Emeritus Professor of Mineralogy in the University of Cambridge.

ON the retirement of Professor A. Hutchinson from the Chair of Mineralogy at Cambridge, at the end of the academical year 1930–1, it was felt by those associated with him in the Department that his services during thirty-five years as Demonstrator, Lecturer, and Professor should be commemorated in some special manner. A subscription was instituted amongst his former pupils, and Sir William Rothenstein kindly undertook the execution of a portrait in oil.

At a gathering in the Library of the Department on Saturday, 12th March, Dr. Herbert H. Thomas, in making the presentation on behalf of the subscribers, referred to Professor Hutchinson's original researches and to the inspiring character of his teaching. The Professor, in expressing his thanks, gave an interesting sketch of the history of the Department during his time, enumerating many eminent men of science who had been his pupils. He also paid tribute to the help he had received from the members of the staff and from the laboratory assistants past and present.

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ORIGINAL ARTICLES.

Some Problems of the Pleistocene Hydrography of Kharga Oasis, Egypt.

By Elinor W. Gardner, M.A., F.G.S., Research Fellow of Lady Margaret Hall, Oxford.

(PLATES XXVI–XXXI.)

Introduction.

FOR the past two winters it has been the author's good fortune to undertake the geological work for Miss Caton-Thompson's investigations into the prehistory of Kharga Oasis. This necessarily involved a close consideration of the water supply in Pleistocene times, the results of which disclosed some interesting new facts and raised climatic questions of more than local interest.

The author gratefully acknowledges financial help from grants from Section "C" of the British Association and the Gloyne Fund of the Geological Society. She would further like to thank Mr. O. H. Little, Director of the Geological Survey of Egypt, for much assistance both in the field and in Cairo throughout the two seasons.

General Physical and Geological Features of the Oasis.

Some knowledge of the present physical and geological conditions of the oasis is necessary to understand the water supply problems—these will now be briefly considered. Detailed accounts can be found in Dr. John Ball's (1)[1] and Mr. H. J. L. Beadnell's (2) books on this region. All workers in the Libyan desert owe a debt of gratitude to these two great pioneers who have done so much towards a fundamental understanding of desert geology and hydrography. If the author's work does not always bear out

[1] The figures in parentheses refer to the Bibliography at the end.